# POWER PLANT ENGINEERING

Established Over 32 Years

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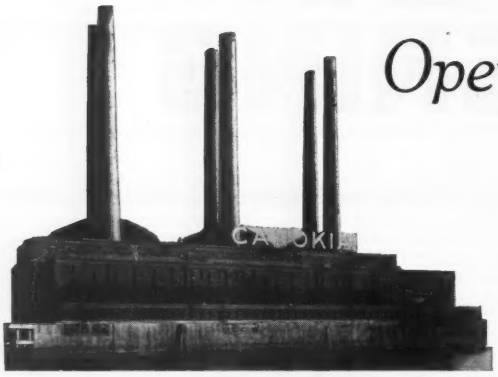
## A Unique Case of Voltage Drop

ELECTRICAL ENGINEERS are great hands at swapping yarns about voltage drop. They are forever worrying about it and seem possessed with the idea that the voltage will drop off their transmission line. This is silly, of course, but the electrical boys are that way (so the steam men say) and they have worked out elaborate schemes for figuring this voltage drop. In this very issue F. C. De Weese, an electrical engineer of no mean ability, presents a discussion of the subject in a manner so simple that, according to the electrical boys, even a steam man can understand it.

These electrical fellows are quite clever at figures but suppose they encountered a real case of voltage drop, such as the one shown above where a considerable quantity of voltage, several tons of it at least we should judge, dropped right smack out of the sky on the tree; could they figure that? With all respect for their ability we presume to doubt it. Just see what happened to the tree. Certainly Humpty Dumpty himself was never in a worse condition. The picture of this lightning-struck tree appeared in a recent number of Tycos-Rochester and we thought it so good that we asked the editor to let us reprint it.



# Operating Experience with Latest Section of Cahokia Station

By

E. H. Tenney and
H. G. Thielscher

FIFTH UNIT, WITH A CAPACITY OF 50,000 KW., BRINGS TOTAL CAPACITY TO 195,000 KW. UNIT MILLS AND AIR PREHEATERS USED WITH NEW BOILERS.

DURING 1927, installation of the fifth turbine unit with accompanying boilers brought the capacity of Cahokia Station to 195,000 kw. This turbine is the first of two for the third section of the plant, the first section of which was put in operation in the fall of 1923 and the second in the fall of 1924. As a result of building the plant in sections, the recent addition represents in design the availability of later and improved equipment and the cumulative experience of four years' operation with a station arrangement and with general operating conditions that have remained unchanged.

There are several specific conditions which, roughly, have determined general design characteristics. First of all, the station has been designed for low grade and low priced southern Illinois coal presenting difficulties in burning in pulverized form and not justifying a high investment in equipment to secure the degree of thermal economy which is commonly justified for stations that have a higher cost fuel. This consideration is further emphasized by the low annual load factor of 45 per cent. As a result of the system load development, the company's older Ashley St. Station is required to augment hydro-electric power and furnish steam to a central steam heating system. Cahokia is therefore not a base load plant.

Photo by Frank Moore.

Another factor in design is determined by building conditions. The station is built upon Mississippi silt, necessitating the use of concrete piles ranging from 30 ft. long on the land side to 75-ft. interlocked piles on river side. Because of a 44-ft. range in river stage from high to low water, a considerable portion of this work has had to be done below river water level and required thorough waterproofing of the structure. Investment in foundations and the lower portion of the building consequently runs high and on this account it has been necessary to keep down the square-footage, as any increase in plant capacity made without increasing the building area represents a saving in investment cost.

Designs made to meet these conditions have previously been covered in technical journals. The general plant arrangement is shown in Fig. 2. It may be noted that the size of the generating units has been steadily increased from 35,000 kw. to 50,000 kw., although, up to the latest turbine, each unit was served by four boilers of the same size. As a result of still further increasing the ratings with unit mill fired boilers, but three boilers have been required for the latest unit in the third section. It is now planned to install 75,000-kw. machines in the incompleted sections of the plant. Future units will then occupy the same space originally allotted to a 35,000-kw. unit, or more than twice the capacity in the same area, resulting in a considerable reduction in building cost per unit of capacity.

Photo by Blank & Stoller.

Other departures from

EDWARD H. TENNEY, Chief Engineer of Power Plants of the Union Electric Light & Power Co., St. Louis, Mo., entered the drafting department of this company in 1905. In 1908, he was appointed test engineer, and in 1911, assistant chief engineer, the position he held until January, 1919, when he was appointed to his present position. During the reconstruction of Ashley Street Station in 1925, when pulverized coal firing was substituted for stokers, he developed the Bailey-Tenney pulverized coal burner. He graduated from the College of Arts and Science at Oberlin in 1903 and in 1905, after post graduate work, received the degree of Mechanical Engineer from Ohio State University.

HERMAN G. THIELSCHER, in charge of mechanical engineering with McClellan & Junkersfeld, Inc., New York, N. Y., started his engineering work in 1911 as test engineer with A. D. Little, Inc. From then until 1916 he held various engineering positions with industrial and manufacturing concerns and in 1916 joined Stone & Webster, Inc., in the Division of Construction and Engineering, spending 6 yr. with them in the design of power plants, industrial plants and report work. Since 1922, he has been with McClellan & Junkersfeld, Inc. He is a graduate of Lowell Institute, completing the Mechanical Engineering course in 1913 and the Electrical Engineering course in 1915.

earlier design are the greater number of stages of feedwater heating; a reduction in condensing surface per kw. of capacity; the change from vertical firing with the storage or bin system of pulverized fuel to horizontal firing and increased turbulence in connection with unit mills; the installation of air heaters on all boilers; and increased water cooling of furnaces.

### Fifth Unit Bled at Four Points

The fifth turbine-generator is rated at 50,000-kw., 0.9 power factor, 13,800 v., 60-cycle, 3-phase. It is a General Electric, 17-stage, single-cylinder turbine with steam extracted at four points. The condenser for this unit is of the standard two-pass design with 56,000 sq. ft. of cooling surface and a circulating pump capacity of 70,000 g.p.m. compared to 53,000 sq. ft. and 54,000 g.p.m. for the earlier 35,000-kw. units. This reduction in condenser size has been made possible partly because of better water rate and increased bleeding, but most of all, by the open lanes for steam distribution. These lanes have reduced the resistance to the steam flow through the condenser and made possible vacuua as good as those with the relatively larger condensers not so designed. There are two circulating water and two condensate pumps both driven by variable speed, slip-ring, wound-rotor, induction motors. The rotative dry vacuum pump is a Laidlaw Feather Valve type driven by motor. In winter, condenser pressures lower than 0.7 in. absolute are regularly maintained and it is believed that the vacuum pump capacity and performance are largely responsible for the ability to run with such low condenser pressures.

TABLE I. PERFORMANCE DATA ON THE COMPLETE STATION FOR THE MONTH OF MARCH, 1928

| | |
|---|---|
| B.t.u. per Lb. Coal | 11,174 |
| % Moisture in Coal | 9.02 |
| % Ash in Coal | 14.10 |
| B.t.u. per Gross Kw. Hr. | 15,313 |
| B.t.u. per Kw. Hr. Delivered | 16,028 |
| Boiler Efficiency Steaming Period (No economizers) | 83.9 |
| Monthly Load Factor | 58.2 |
| Lbs. Steam per Kw. Hr. Sent out | 11.92 |
| Kw. Hrs. Sent Out | 68,153,000 |
| Station Capacity, Kw. | 195.000 |
| Steam Pressure, Lbs. Sq. In. Ga. | 330 |
| Steam Superheat, average °F | 260 |
| Average Back Press., In. Hg. | 0.71 |

In Fig. 3, the general diagram of the heat balance is indicated. In general, this heat balance is the result of the development in preceding sections of the plant where satisfactory and reliable service was obtained with similar arrangements, the major change being the addition of a fourth extraction heater. The principal feature of this arrangement is that it is not necessary to manipulate any of the heat balance equipment when starting up or shutting down the main turbine, thereby making the heat balance equipment automatic in its operation. Heater drainage pumps have been eliminated by carrying the drips back to preceding heaters. Feedwater temperatures are allowed to vary with the load on the turbine, no attempt being made to regulate the heaters to maintain a constant temperature of water going to the boilers.

### Raw Water Heat Exchanger Used with Generator Air Cooler System in Summer

Cahokia Station was one of the first to use the closed type of generator air cooler and a description of the solution of the cooling water problem for this air cooler is believed worth while repeating since the system has been in successful operation for 5 yr. The use of circulating water in the generator air cooler is not desirable on account of dirty water in the Mississippi River during many periods of the year. Condensate is therefore passed through the generator air cooler directly from the condenser hotwell as indicated on the diagram. During the summer, the Mississippi River gets up to 87 deg. F. with resulting condenser pressures of around 2 in. so that condensate temperatures run too high for suitable generator air cooling. During these periods, the condensate is passed through a large water-to-water heat exchanger where the 87 deg. F. injection water is used as a cooling medium to reduce the temperature of the condensate 5 to 10 deg. before going to the generator air cooler.

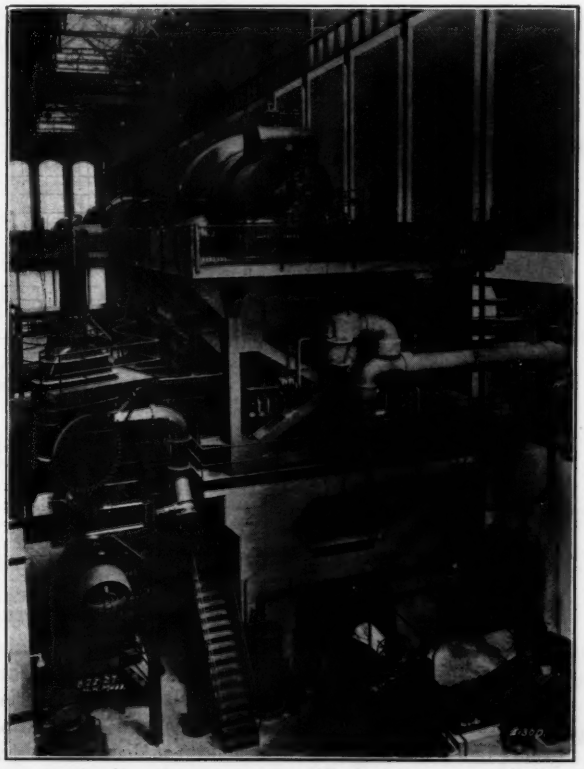


FIG. 1. TURBINE ROOM OF CAHOKIA, SHOWING THE FIVE TURBINES WITH UNIT NO. 5 IN THE FOREGROUND

By using this arrangement, the objectionable circulating water is confined to the straight tubes of the heat exchanger. These can be cleaned out more easily than the generator air cooler tubes and without interfering with turbine operation. Another advantage as compared with placing additional river water cooling surface in the air circuit is in the elimination of the extra air pressure drop across this additional surface with a consequent increase in generator fan power. During the brief period of use of the heat exchanger,

there is some slight loss in heat but, due to the greater amount of heat absorbed by the stage 14 bleeder, this loss is largely offset with negligible difference in the thermal efficiency of the cycle. At light load operation, it is sometimes necessary to recirculate some of the condensate back to the condenser to obtain sufficient cooling water, since the generator losses do not fall off appreciably with the load.

### Boiler Room

Progressive development of boiler and furnace design is set forth in Table II, while Table III summarizes the improvement in evaporative performance, both for efficiency and rating. The improved efficiencies have been accompanied by lower maintenance and operating costs, largely a result of reduced slagging and brick work erosion, and improvements in the coal preparation process. In addition, there has been a decrease in the unit investment cost effected by simplification in design, by units of larger capacity and decreased construction labor costs. The fact that the same size of boilers (1800 b.hp. throughout) are producing 50 per cent to 100 per cent more steam has also materially decreased unit investment costs.

Illinois coal, on which the station was operated until the 1927 strike in this field, contains from 10 to 12 per cent moisture, and drying with the storage system was found obligatory. The first two sections of the plant were equipped with dryers of the waste heat type and the maintenance due to corrosion of dryer sides has been a considerable item. These dryers were satisfactory in the removal of moisture but when coal became stationary, occasional fires resulted. It was recognized that this created a serious hazard, for incandescent coal in the mills could cause explosions. Although some slight changes and constant vigilance greatly reduced the number of dryer fires, occasional "hot spots" are still found. A vigorously applied code of safety instructions has prevented any trouble except for a few comparatively harmless puffs.

At the time the first section was put in operation, the largest pulverizing mills available had a capacity of but 6 t. per hr. The next section was equipped with 15 and 20-t. mills, the first to be made of such capacities, and the operating attention and maintenance per ton of capacity was naturally reduced, along with the power consumption. This latter value averaged about 28 kw-hr. per t. (total for coal preparation) in the first section and was cut to about 22 kw-hr. per t. in the second section.

Although the dryers and mills reduce the moisture to about 5 per cent, the pulverized coal transport lines are occasionally blocked by coal which seems to gather into balls of a "gummy" consistency at switching valves. The wear on transport piping, especially at bends, has been materially reduced by the use of wearing plates but it is still a considerable item. There is some loss of coal through cyclone vents but it has not been possible to measure this.

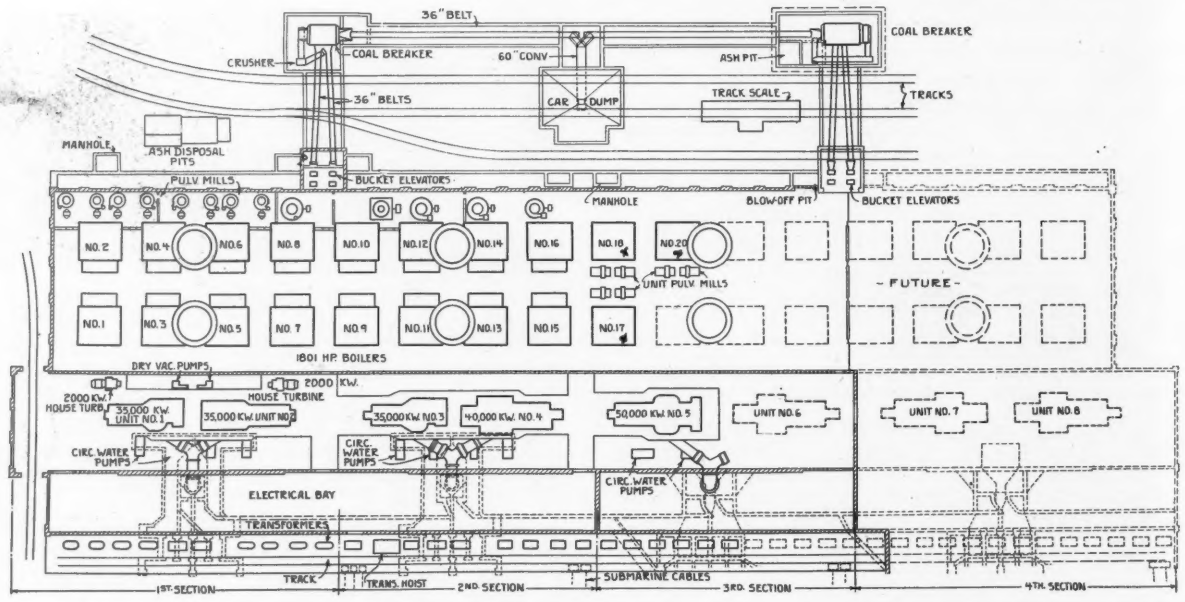



FIG. 2. PLAN OF THE STATION AT THE OPERATING FLOOR WITH THE COMPLETED PORTION IN SOLID LINES

Storage of pulverized fuel has presented no particularly severe problems, although a tendency on the part of the bunker walls to sweat and the coal to pack, has caused individual burner feeders to block or feed unevenly. This results in erratic furnace conditions. As a whole, then, the coal preparation system has been one that has required a great deal of attention and vigilance. Although the cost of power, operation and maintenance was reduced approximately 20 per cent in the second section, as compared to the first section, the cost of preparation is still a considerable item.

Problems involved in the combustion of the Illinois coal used have been thoroughly covered in previous articles on Cahokia. Briefly the difficulties have been: 1, uneven feeding of the coal to the furnace; 2, a high

temperature zone immediately above the ashpit caused the low fusing temperature ash (2000 deg. F.) to slag over the pit; 3, this condition and refractory erosion have limited ratings and the reduction of excess air. An outage factor for cleaning ashpits of slag has run as high as 25 per cent of the boiler service hours. The renewal of refractory sidewalls was expensive and in 1925 accounted for 31 per cent of the corresponding total station maintenance. It may be noted that fin tube sidewalls on No. 11 and 13 boilers greatly reduced this expense. With vertical firing, however, it was not found possible to avoid slagged pits, nor to exceed 220 per cent rating without greatly increasing slagging difficulties.

These facts are included to show that although successive changes in design and greater skill in operation have materially decreased the boiler operating costs, it was indicated that there were possibilities for improvement in the third section. Further, the points at which the expense was incurred and the nature of the difficulties were both known in considerable detail and accuracy.

At the same time, in a long developmental period with a unit mill system, considerable experience was being collected at the Ashley St. Station where ultimately twenty-four 558-hp. boilers have been so equipped. An experimental study with two small 8000 lb. per hr. unit mills on No. 11 boiler at Cahokia, and another study with a 15,000-lb. mill on two boilers at Ashley St. showed that with certain changes a similar arrangement offered possibilities with 1800-hp. boilers at Cahokia. For the third section the design shown in Fig. 6 was developed. Data on one of these boilers, No. 17, is included in Table III. Three such boilers have been in continuous service for nearly 9 mo., during which considerable operating experience and data on evaporative tests have been collected. The boilers are Babcock & Wilcox cross-drum, 20 tubes high, 38 tubes wide, 20-ft. long tubes with interdeck superheaters giving a total steam temperature of 725 deg. F. It has been demonstrated that continuous ratings up to 450 per cent are possible; that slagging in the ashpit is almost wholly eliminated; and that the 15,000-lb. unit mills are performing substantially as expected, being entirely dependable.

### Grinding 65 Per Cent Through 200 Mesh Appears to Be Most Satisfactory

These mills, of the high speed impact type, constructed by the Furnace Engineering Co., are the first of this size to be built. Two 15,000-lb. unit mills serve each boiler, each mill being capable of firing the boiler at 275 per cent of rating. A wide range of fineness of grind is possible through the adjustment of clearances within the mills. A grind of 65 per cent through 200 mesh is giving good furnace conditions and at present this appears to be the most satisfactory point at which to operate.

Increased capacities and improvement in slagging conditions referred to are accounted for by greater turbulence and quicker burning, due to the type of burner where all the air and coal are admitted to the furnace intimately mixed and because, with horizontal firing, the hot zone of the furnace is no longer located immediately above, or in the ashpit, as in the earlier installations, but higher up toward the center of the furnace where the heat is dissipated to the water-cooled sidewalls. The ashpit floors are also water-cooled, consequently no water screen is needed.

Water-cooled walls in these furnaces have been designed to maintain proper temperatures for complete combustion within the furnace and yet with the hot zone moved to the top of the furnace, absorb sufficient heat to avoid slagging of the ashpit. Two types of furnace have been installed with these three boilers. One consists of 4-in. tubes, spaced on 7-in. centers set in chases in a refractory wall. This furnace is outlined in Fig. 6. It is to be noted that all four sides of the boiler are water-cooled in this manner, with only a slight section of the side walls not protected with the cooling tubes. Two boilers installed in 1925 for Unit 4 were equipped with recessed tube furnaces and al-

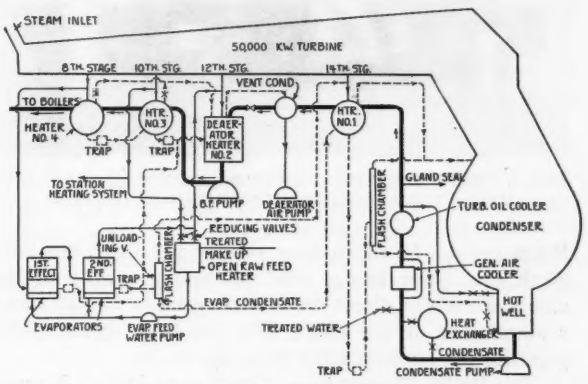



FIG. 3. HEAT BALANCE DIAGRAM OF UNIT NO. 5

though designed for lower combustion rates have given such satisfactory service that further development of this design was thought advisable. By spacing the tubes closer increased combustion rates have been obtained. These furnaces give every promise of being as successful at these higher rates as their predecessors have been under their operating conditions. The refractory part of the wall is sectionally supported by cast-iron angles attached to buckstays to eliminate heavy unit brick loads and facilitate brick and tube repairs should these be necessary. The bottom of this furnace is constructed with the Furnace Engineering Company's cast-iron block covered tubes and considerable storage capacity is available below the throat of the furnace for the storage of ash.

### No Marked Difference in Operation Noticed Between the Two Boiler Types

The other type of furnace installed has a Bailey cast-iron covered block furnace bottom, Bailey refractory covered block inclined front wall and Bailey part bare cast iron and part refractory covered cast-iron rear wall with recessed tube side walls. It was thought that ignition might be hastened by the entire refractory covering of the front wall and partial refractory rear wall but operation to date does not indicate any marked difference in either furnace. Both are standing up well under furnace heat liberation rates as high as 30,000

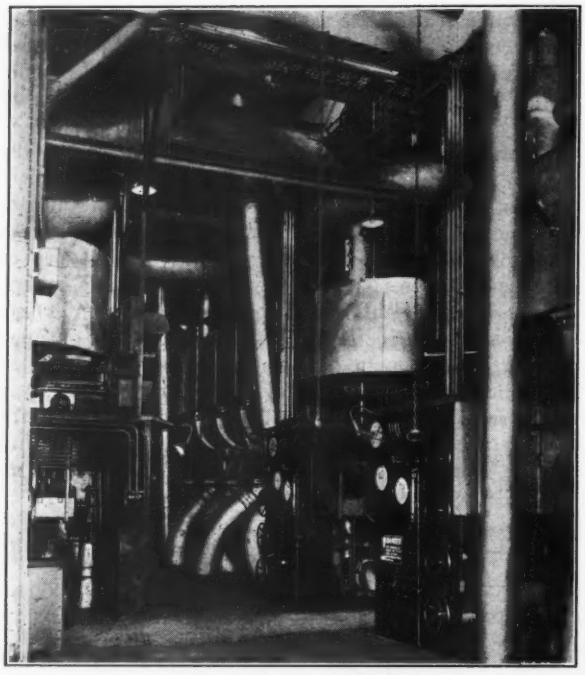


FIG. 4. VIEW OF THE OPERATING LEVEL OF THE UNIT MILL FIRED BOILERS IN THE THIRD SECTION

B.t.u. per cu. ft. of furnace volume per hour, the only weak spot being in the solid refractory portion of the side walls where direct flame impingement washed away a small part of the wall. This has been corrected by pointing the burners away from the walls.

The Bailey-Tenney type of turbulent burner is used, four 18-in. burners being set horizontally across the setting with preheated secondary air admitted through a housing around each burner. Preheated air is also used for sweeping the mills, the normal temperature ranging from 250 to 300 deg. F. Up to 10 per cent moisture, coal has been pulverized successfully without drying and upwards of 8500 lb. of coal per hr., per burner, has been fired. The preheated air is obtained from a Sturtevant vertical type air heater of 9920-sq. ft. heating surface, with two forced and one induced draft fan. The forced draft fans are driven by one pole-changing two-speed induction motor and the draft fan by a similar motor. The equipment is arranged so that if desired the boiler can run natural draft while cleaning out the gas side of the air preheater. All dampers and fan motor controls are located on the boiler operating panels. Operation discloses that the air heaters are kept clean by the scrubbing action of the gases and since in this case the temperatures are never reduced in operation below the dew point of the gases no corrosion has been experienced to date. The boilers have been run at 300 per cent of rating without the induced draft fans and with the air heaters by-passed.

Some difficulties were experienced in the early operation with the air heaters, due to the high difference in pressure between the gas and air side of the heater, causing the plate elements to bulge inward toward the gas side. This matter has been remedied by additional spacing angles which also serve as guide vanes in the gas spaces, so that no further trouble has developed. The air heaters have not only justified themselves from an efficiency point of view but, due to the great increase in capacity of the boilers with an efficiency equal to the efficiency of the older boilers at much reduced rating without air heaters, there has been a substantial saving in investment.

General arrangement of the mill layout and raw coal bunker with its supply connections are shown in Fig. 6. By keeping all bins with steep sides and making

TABLE II. BOILER AND FURNACE DATA ON THE 19 BOILERS IN SECTIONS I, II AND III

| | Boilers 1,2, 3,5,7 and 8* | Boiler 11** | Boilers 13 and 15 | Boilers 14 and 16 | Boiler 17 Blr. 18 and 20 |
|---|---|---|---|---|---|
| Boiler Heating Surface, sq. ft. per boiler | 18,010 | 18,010 | 18,010 | 18,010 | 18,010 |
| Superheating Surface, sq. ft. per boiler | 3,090 | 4,070 | 4,070 | 3,090 | 3,790 |
| Water Screen Surface: | | | 905 fin. | | |
| Side Wall tubes, sq. ft. and type | None | 940 fin | 66 plain | 324 plain rec. | 465 plain rec. |
| Front Wall | None | None | None | None | 93 plain rec. (Bailey Refractory) |
| Rear Wall | 223 plain | 566 fin | 540 fin | 502 plain | 238 plain rec. (Bailey Block, Ref. and Bare) |
| Slag Screen | 358 plain | 382 plain | 380 plain | 503 plain | None |
| Hopper Bottom | None | None | None | None | 479 Bare Iron (Bailey Bare Iron) |
| Total Water Screen, sq. ft. per boiler | 581 | 1,888 | 1,891 | 1,329 | 1,275 |
| Total Heating Surface per boiler, sq. ft. | 21,681 | 23,968 | 23,971 | 22,429 | 23,075 |
| Furnace Volume per boiler, cu.ft. | 11,750 | 13,500 | 13,200 | 13,000 | 12,000 |
| Furnace Volume, cu.ft. per rated hp. | 6.5 | 7.5 | 7.3 | 7.2 | 6.65 |
| Distance, Arch to Slag Screen, ft. | 22.0 | 22.5 | 21.5 | 22.5 | - |
| Width of Furnace, Top ft. | 17.8 | 20.7 | 18.7 | 18.7 | 19.2 |
| Bottom ft. | 16.0 | 20.7 | 18.7 | 18.7 | 19.2 |
| Air Heater, sq. ft. heating surface | None | None | 11,700 | None | 9,920 |
| Firing | Storage System | Storage System | Storage System | Storage System | Unit Mills |

Furnace Volume from above centerline slag screen tubes to centerline of lowest boiler tubes, except on Boilers 17,18 and 20. On these boilers, the volume is measured from the lowest row of boiler tubes to the horizontal centerline thru the hopper throat.
Width of Furnace measured between sidewalls or between inner faces of tubes.
Fin Tube Surface based on 1/2 entire perimeter of fin and tube. Screen surface for Boilers 14 and 16 based on entire tube surface. Plain tube surface of Boilers 13,15 and 17, based on projected diameter of tubes, and Bare Iron Surface is actual block surface.

* Note - Boilers 4,6, and 10 have been changed to Fin tube side wall
**Note - Boilers 9 and 12 similar to Boiler 11 except refractory side walls and plain tube rear wall.

raw coal pipes nearly vertical without bends or flat angles, the coal feed to the mill requires little or no attention. It has been possible to maintain a high degree of cleanliness around the mills, since all parts are easily kept tight against dust leakage. With the arrangement shown, one mill operator and an assistant can readily take care of the mills for eight boilers and by concentrating all the necessary mill, furnace and boiler accessory controls on a central panel board, one boiler operator will take care of three boilers now and a fourth later, controlling a total output of 1,000,000 lb. of steam per hour.

### Coal and Ash Handling

Cahokia Station was laid out to handle coal direct from the cars by means of a car dumper to the inside storage and this system was extended for the fifth and subsequent units. As now developed, there is one car

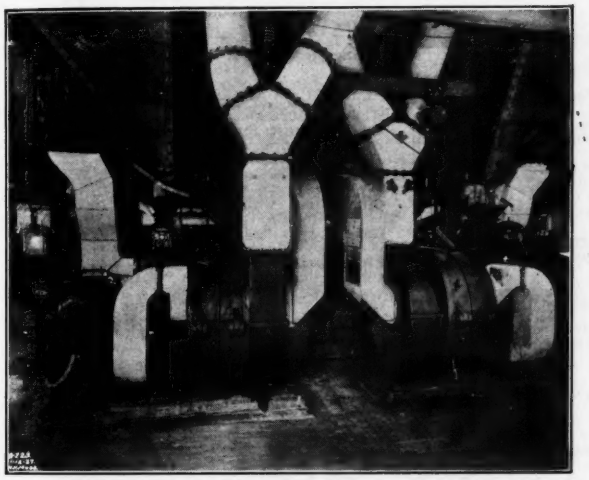


FIG. 5. TWO 15,000-LB. PER HR. UNIT MILLS SERVE EACH BOILER

dumper with two rotating coal breakers, each breaker discharging into duplicate conveyors and elevators to the raw coal overhead storage. In connection with the second breaker installed with the fifth unit, some changes in the general arrangement have been made to improve operation.

In the first breaker installation, the tailings were discharged onto a picker table and from that to a ring roll crusher which delivered everything that passed the picker table into the system. This arrangement has been changed to do away with the ring roll crusher so that the tailings now deliver onto a series of pan conveyors and picker table, the discharge of which again returns any material left to the breaker, being recirculated until finally picked out. Much undesirable material which previously entered the system by way of the ring roll crusher is therefore eliminated. In pulverized fuel plants, using impact pulverizers, it is important to eliminate tramp iron from the mills. Magnetic separators have been provided on the belt conveyors leading to the coal elevators. These separators are interlocked with the conveyor drive motors so that it is not possible to run these unless the current is on the magnetic separator. In addition to this protection, each mill is provided with magnetic separators,

TABLE III. COMPARISON OF DIFFERENT BOILERS AT CAHOKIA FROM TEST RESULTS. (NO ECONOMIZERS USED AND NO ALLOWANCE MADE FOR POWER CONSUMPTION)

| Boiler No. | 3 | 11 | 13 | 14 | 17 |
|---|---|---|---|---|---|
| Type of Wall Other Equipment | Refractory | Fin Tube | Fin Tube Air Heater | Spaced Tube | Spaced Tube Unit Mills Air Heater |
| | | | Rating for Best Efficiency | | |
| Rating % | 150 | 135 (or below) | 190 | 135 (or below) | 165 |
| Efficiency % | 86.00 | 86.75 | 87.15 | 84.85 | 88.85 |
| % $CO_2$ Top 3rd Pass | 13.0 | 13.2 | 14.7 | 12.5 | 16.1 |
| Total Steam Temp°F | 670 | 656 | 670 | 686 | 685 |
| | | | 200% Rating | | |
| Efficiency % | 83.50 | 85.50 | 87.15 | 84.20 | 88.20 |
| % $CO_2$ Top 3rd Pass | 12.7 | 13.2 | 14.6 | 12.5 | 15.9 |
| Total Steam Temp°F | 705 | 670 | 680 | 700 | 695 |
| | | | 250% Rating | | |
| Efficiency % | 81.00 | 81.40 | 86.85 | 81.70 | 87.05 |
| % $CO_2$ Top 3rd Pass | 12.3 | 13.3 | 14.4 | 12.7 | 15.7 |
| Total Steam Temp°F | 725 | 705 | 720 | 720 | 705 |
| | | | 340% Rating | | |
| Efficiency % | Above Cap. | Above Cap. | 82.90 | Above Cap. | 82.90 |
| % $CO_2$ Top 3rd Pass | | | 14.1 | | 15.1 |
| Total Steam Temp°F | | | 730 | | 720 |
| | | | 380% Rating | | |
| Efficiency % | Above Cap. | Above Cap. | Above Cap. | Above Cap. | 79.70 |
| % $CO_2$ Top 3rd Pass | | | | | 14.6 |
| Total Steam Temp°F | | | | | 730 |

thus doubly safeguarding the system against iron. In spite of these precautions, iron sometimes gets into the mills and occasionally causes damage which, however, is usually slight, such as stripping off some of the mill paddles. In general, any iron which passes by the magnetic separators falls to the bottom of the mill into the tramp iron pocket which has been provided.

Ash from the boilers is handled by an hydraulic sluice manufactured by the Allen-Sherman-Hoff Co.

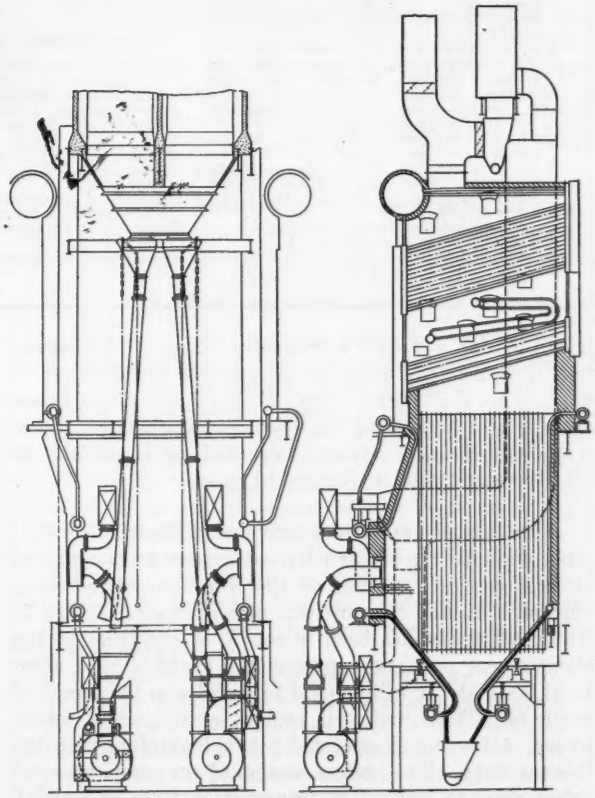


FIG. 6. ARRANGEMENT OF THE MILLS AND GREEN COAL BUNKERS (LEFT) AND A CROSS SECTION OF BOILER NO. 17 (RIGHT)

This sluice is a development of previous installations at Cahokia and primarily due to the much improved furnace conditions, ash handling conditions are excellent. Practically all material removed from the furnace bottoms is in fine granular shape which is discharged through the ash sluice to a grizzly screen where the water and fine material are pumped out. The ash pumps in use for this service are Morris Machine Co.'s manganese lined dredging pumps and aside from the wear of the impeller give very good service. It is necessary to replace the impellers about once every year and a half. Any oversize material which does not pass through the grizzly is delivered into a second pit where it can be dug out with a locomotive crane. This operation is infrequent, since practically all the material is handled by the pumps. The Cahokia Plant under maximum winter conditions has been burning about 1700 t. a day and the raw coal and ash handling is confined to one operating shift requiring 12 men.

## Principal Mechanical Equipment, Third Section, Cahokia Station

### General

Company—Union Electric Light & Power Co.
Engineers—McClellan & Junkersfeld, Inc.
Location—On Mississippi River, near St. Louis, Mo.
Present capacity—195,000 kw.
Section 1—70,000 kw.
Section 2—75,000 kw.
Section 3—50,000 kw.

### Boilers and Auxiliaries

3 Babcock & Wilcox Co. 18,010-sq. ft. boilers with 3789-sq. ft. interdeck convection superheaters.
6 Furnace Engineering Co. simplex 7½-t. per hr. unit mills, each mill driven by 150-hp. General Electric motors.
12 Fuller Lehigh Co. Bailey-Tenney burners.
3 B. F. Sturtevant Co. 9920-sq. ft. air preheaters.
6 B. F. Sturtevant Co. 40,000-c.f.m. forced draft fans, driven by 125 and 60-hp. General Electric two-speed motors.
3 B. F. Sturtevant Co. 180,000-c.f.m. induced draft fans. Driven by 200 and 60-hp. General Electric two-speed motors.
Soot blowers—Diamond Power Specialty Co. (20 units per boiler).
Feedwater regulators—Northern Equipment Co. Copes (2 per boiler).
2 A. S. Cameron Steam Pump Works five-stage, 1500-g.p.m. boiler feed pumps, driven by 575-hp. Allis-Chalmers motors.
Control equipment—Bailey Meter Co.
Uptake and flues—Connery & Co.
Air ducts—John Nooter Boiler Co.
Chimneys—Wiederholdt Construction Co.
Refractories—LaClede Christie Clay Products Co., Evans & Howard Firebrick Co., Walsh Fire Clay Products Co.
Brickwork erected by—G. Seeger.
Boiler insulation—Johns-Manville Corp.
Boiler No. 17:
Side and rear wall—Walsh & Weidner Co.
Front wall, suspended—LaClede Christie Clay Products Co.
Water wall headers—Heine Boiler Co.
Hopper bottoms—Furnace Engineering Co.
Boilers No. 18 and No. 20:
Side wall, face tube and refractory—Walsh & Weidner Co.
Rear wall, arch and hopper bottoms—Fuller Lehigh Co.
Ash sluice—Allen-Sherman-Hoff Co.
Ash disposal pumps—Morris Machine Works.
Conveyors—Link-Belt Co.
Conveyor belting—Boston Woven Hose & Rubber Co.
Crushers—Pennsylvania Crusher Co.
Magnetic separator—Dings Magnetic Separator Co.

### Prime Movers and Auxiliaries

1 General Electric Co., single-cylinder, 50,000-kw., 0.9 per cent power factor, 13,800-v. turbo-generator.
1 Worthington Pump & Machinery Corp. 56,000-sq. ft. surface condenser with No. 20 B. W. G. admiralty tubes furnished by Bridgeport Brass Co.
4 Link-Belt Co. 72-in. intake water screens.
Circulating, condensate, R. G. B. pumps—Worthington Pump & Machinery Corp.
Evaporators—Griscom-Russell Co., 35,000 lb. per hr.
Deaerators—Cochrane Corp., 600,000 lb. per hr.
Heat exchanger and closed heaters—Whitlock Coil Pipe Co.
Jacket water coolers—Griscom-Russell Co.
Generator air coolers—General Electric Co.
Raw feedwater and sump pumps—Worthington Pump & Machinery Corp.

### Piping, Valves and Coverings

High pressure steam and boiler feed piping—Midwest Piping & Supply Co.
High pressure steam piping for turbine room—Crane Co.
High pressure steam manifold—M. W. Kellogg Co.
Circulating water piping—Steere Engineering Co.
Gate valves, high pressure steam lines—Crane Co.
Sluice gates—Coffin Valve Co.
Circulating water gate valves—Kennedy Valve Mfg. Co.
Gate and swing check valves for boiler feed lines—Chapman Valve Mfg. Co.
High pressure pipe covering—Johns-Manville Corp.
Remote valve control—Payne Dean, Ltd.

### Switch-House

Disconnect switches—Champion Switch Co.
Oil circuit breakers—Westinghouse Electric & Mfg. Co.
Switchboard equipment — Westinghouse Elec. & Mfg. Co.
Conduits, Sherardized iron—Graybar Electric Co.
Auxiliary transformers—Maloney Electric Co.
Main transformers—General Electric Co.
Outdoor disconnect switches—Railway & Industrial Engineering Co.
Rockbestos cable—Rockbestos Products

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Eastern Shore Public Service Co., Salisbury, Md., has completed the construction of a new steam-operated electric generating plant on the Nanticoke River, near Vienna, Md., and the unit was placed in service May 7. The new station has been in course of construction for about a year past and represents an investment of close to $1,000,000. It will be used for service in the territory south of Elkton and will replace a number of small hydro, steam and oil-operated plants heretofore used for this territory. The present system of the company comprises close to 300 mi. of transmission lines and about 325 mi. of distributing system. The company is a subsidiary of the National Public Service Corporation, N. Y.

## A.S.H. & V. E. to Hold 34th Convention June 26 to 29

At the West Baden Springs Hotel, West Baden Springs, Ind., the American Society of Heating & Ventilating Engineers is to hold its 34th semi-annual meeting from June 26th to 29th next.

Program of papers has been divided into three main sections. Consideration is being given to domestic heating by oil and gas, air conditioning problems and codes and research investigations. Registration, in charge of R. W. Noland, will begin on Tuesday morning, June 26th.

The first session will be opened by President A. C. Willard at 2 p. m. on June 26. On Wednesday, Thursday and Friday the technical sessions will be held from 9:30 a. m. to 1 p. m. C. R. Ammerman, Indianapolis, Ind., is chairman of the committee on arrangements.

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Department of Commerce announces that for the month of March, 1928, 12 establishments sold 123 mechanical stokers installed under 43,425 hp. of boilers. Of this number 31 were under 5078 hp. of fire tube boilers and the remainder under water tube boilers. Stoker sales increased from 85 in February to 123 in March, while the capacity of boilers under which they were installed decreased slightly from 43,643 in February to 43,425 in March.

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Wear your learning like a watch, in a private pocket; and do not pull it out and strike it merely to show that you have one.—Chesterfield.

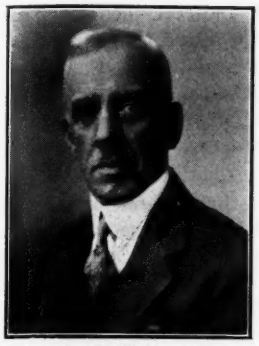

Photo by Moffett.

# Correlation of Actual Costs and Engineering Estimates

OUTLINE OF THE COST ESTIMATE AND REPORT SYSTEM AS USED BY THE BYLLESBY ENGINEERING AND MANAGEMENT CORPORATION

BY

*H. W. Fuller and W.B. Rittenhouse*

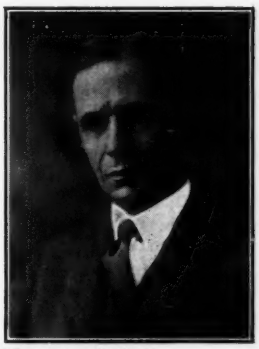

Photo by Moffett.

CORRELATION of predicted costs with actual costs is of interest and importance to all engineers and contractors who are engaged in general practice, even though the number of projects in which they engage at any one time is limited. When estimating, designing, purchasing of equipment, supervision of construction work and accounting for an extensive group of projects covering practically the entire United States are largely concentrated in a central engineering organization, a definite procedure covering these matters becomes of importance, even greater than when local or smaller organizations perform the same functions for each of the individual projects.

Several years ago, expansion of the Byllesby Enginneering and Management Corporation's activities forced attention to the necessity of formulating standards to govern the entire procedure connected with the engineering and construction of new projects. Such a set of standards was prepared and is now in effect, with the result that the functions and duties of the various divisions of the engineering and construction departments have been defined and coordinated. Field forces working in widely separated localities have been brought into closer contact with the central organization and scheduling of work, estimating and cost keeping have been greatly facilitated through the employment of uniform methods.

An essential part of these standards is a standard classification of construction accounts with a correlated system of field reports. A feature which distinguishes this from many somewhat similar systems lies in the fact that, while complying with recognized accounting procedure, the line of attack has been primarily that of the engineer.

For the past two years, the system has been in effect on the company's major construction projects. It has succeeded to a gratifying degree in placing in the central office a system of current reports conveying a clear impression of the status of projects under construction, with sufficient information to forecast and localize probable over-runs in time to apply corrective measures.

## STANDARD CLASSIFICATION FORMS ACCOUNT BASIS

This standard classification is based on the Uniform Classifications of Accounts for Electrical and Gas Utilities prepared by the National Association of Railway and Utilities Commissioners; the Uniform System of Accounts for Electric Railways prescribed by the Interstate Commerce Commission; and, in part, on various state commission classifications.

Fixed capital accounts taken from these sources have been set up as major accounts and subdivided into submajor accounts, each representing a sub-system, or func-

HARRY W. FULLER, vice president of Byllesby Engineering and Management Corporation, in charge of engineering and construction, and vice president of H. M. Byllesby and Co., was born in New York and graduated from Rutgers College in 1891. He entered the electrical industry immediately, assisting in the electrification of the horsecar lines at Paterson, N. J.

Following this, he was with the General Electric Co. and the Consolidated Traction Co. of Newark. He remained with this company and its successor, the New Jersey Street Railway, as superintendent and assistant general manager, until 1901, when he became general manager of the Washington Railway and Electric Co. and the Potomac Electric Power Co.

From 1911, Mr. Fuller has been continuously connected with the Byllesby organization, serving as vice president and general manager of the Appalachian Power Co., Bluefield, West Virginia, then as vice president of the Louisville Gas and Electric Co., and vice president in charge of operation of the Northern States Power Co., the position he held until his election as vice president in charge of engineering and construction of Byllesby Engineering and Management Corp.

WALTER B. RITTENHOUSE, production engineer of Byllesby Engineering and Management Corp., graduated from Stevens Institute of Technology in 1898 and started his engineering career as junior mechanical engineer with the International Paper Co.

A year later, he was appointed chief engineer of one of their subsidiaries, the Piercefield Paper Co., resigning the following year to join the engineering force of the Highland Canal & Power Co. of Duluth, later the Great Northern Power Co., where after a short period of field work, he occupied successively the positions of hydraulic engineer, assistant chief engineer, superintendent, chief engineer and assistant general manager.

Since then, except for a year of travel, he has been with H. M. Byllesby & Co. and the associated Byllesby Engineering and Management Corp., where, preceding his appointment as production engineer he was engaged chiefly in special investigations and report work with occasional assignments to the field in charge of engineering work of projects under construction.

tional group, within the project work. These, in turn, have been subdivided into detailed accounts covering specific items on which estimates are made and costs are kept. This classification covers a broad range in the field of construction work and is accompanied by detailed instructions regarding its use both for estimating and cost keeping. It is supplemented by a system of standard forms for estimates, cost reports, quantity reports, progress reports and final job analyses.

Three general classes of accounts are provided for by the classification:

1. Specific Construction Accounts representing the permanent physical features of the project. During the progress of the work, labor and material costs directly allocable to these accounts are the only charges made to them. At the close of the construction period, they absorb the indirect and overhead costs and thereafter constitute a detailed record of the entire cost of the project.

2. Temporary Clearing Accounts for the accumulation of indirect charges which, from their nature, cannot, at the time they are incurred, be directly charged to any specific construction account. Examples of such clearing accounts are construction equipment, local transportation, temporary roads and railways, temporary service facilities and construction camp costs. With some exceptions noted later, the clearing accounts remain intact until the close of the construction period when they are apportioned to the specific construction accounts on their service record or on some other rational basis.

3. General Accounts representing charges of such a nature that they can be prorated to the major construction accounts only on a percentage basis at the close of the construction period. Such accounts include local administration during construction, engineering, interest during construction, and similar charges.

### Two Outstanding Features Incorporated

Two outstanding features of the system are: provision for constantly maintaining a comparison between estimates and actual costs for each element of the project and for providing current revisions of the estimate as the work of construction proceeds. To enable these advantages to be realized, estimates must be made and costs reported in exact accordance with the classification. Furthermore all indirect costs chargeable to clearing accounts, as well as general costs, must be estimated specifically and not merely perfunctorily covered by some more or less customary percentage. When additional sub-accounts prove necessary for a certain project, they are set up and, if of a general nature, may be added to the standard classification for future use.

In order that each element of the work may be estimated by those best qualified, the adopted procedure is for the designing engineers of the central office to estimate the direct labor and material costs of all the specific construction accounts applicable to the project, including in their estimate such allowances for contingencies as they consider proper under each major group of accounts. They also prepare the necessary specifications and drawings.

All costs falling under the indirect, or clearing, accounts are estimated by the Construction Superintendent, since these, with few exceptions, cover matters under his control. He also checks the labor estimates of the engineers and, in conjunction with the engineers and purchasing department, prepares a construction schedule for the project.

The addition of general cost estimates and the assembly of the finished estimate with specifications, drawings and schedules are completed by the Production Division.

### Indirect Construction Costs Carried in Temporary Clearing Accounts

Another distinguishing feature of the Byllesby system is the manner of defining and handling indirect construction costs, or those to be carried temporarily in clearing accounts. As these costs are incurred they are charged to the proper clearing accounts even though in many individual cases they may be of such a nature that it would be possible to charge them directly to the specific construction account to which they apply and to which eventually they will be apportioned. The purpose of this is, during construction, to maintain each clearing account intact for comparison with the estimate for that account. A direct charge of this nature to a specific construction account would vitiate such comparison, not only for the clearing account but also for the construction account affected. An accumulation of many such charges would soon render all comparisons meaningless.

Objections may be made to this method of deferring the apportionment of indirect charges on the ground that it causes extra work at the end of the job and involves a risk of making an incorrect apportionment. The reply is that a true comparison of estimate and cost is a vital necessity which is worth its cost. Provision, however, is made for immediate apportionment of an indirect charge when its nature is such as to make possible its allocation at once to a specific construction account. This is done by first charging it to the proper clearing account and then by a credit entry transferring it to the appropriate construction account and there charging it to a special sub-account to be opened for this purpose, in order that it may not lose its identity. This sub-account will require no comparison with the estimate, since the gross amount (not the net balance) in the clearing account will still be comparable with the original estimate for that clearing account.

The purpose of keeping costs and estimates of each account on a strictly comparable basis is to localize and draw attention to over-runs and under-runs and to give assurance that all wide variations from the estimates are, in fact, what they purport to be and are not due to the inclusion of extraneous matter properly chargeable to another account. All of this is for the purpose of producing cost information free of all ambiguity for use in future estimating.

An engineer estimating the specific construction cost of a water wheel unit and its accessories includes in his estimate the cost of the equipment, freight on board the nearest delivery point and the cost of labor and miscellaneous material required to erect the unit and

OFFICIAL ESTIMATE NO. 11893 DATE 1-10-29 IMPROVEMENT REG'N NO. 14502 ENG. CONT. OR CHI. W. O. 25914

COMPANY States Power Company, DIVISION WORK Additional 20,000 K. W. unit -

| ACCOUNT | ACCOUNT NAME | QUANTITY | UNIT COST | LABOR | MATERIAL | TOTAL |
|---|---|---|---|---|---|---|
| 12 A | POWER HOUSE BUILDING | | | | | |
| 12 A 1 | POWER HOUSE SUBSTRUCTURE | | | | | |
| 12 A 11 | Test holes and exploration | | | 1,000. | 200. | 1,200. |
| 12 A 12 | Removing obstructions | | | 3,000. | 500. | 3,500. |
| 12 A 13 | Excavation | | | | | |
| 12 A 131 | Water removal | | | 5,000. | 1,000. | 6,000. |
| 12 A 132 | Shoring, bracing & wood sheet piling | piling | | 1,000. | 3,000. | 4,000. |
| 12 A 133 | Sheet steel piling | 300 tons | 85.00 | 4,500. | 21,000. | 25,500. |
| 12 A 134 | Earth excavation | 6,720 cu. yds. | 2.00 | 12,440. | 1,000. | 13,440. |
| 12 A 135 | Rock excavation | 500 cu. yds. | 3.50 | 1,200. | 550. | 1,750. |
| 12 A 14 | Backfill | 3,800 cu. yds. | 1.25 | 4,750. | | 4,750. |
| 12 A 15 | Bearing piling | | | | | |
| 12 A 151 | Wood piling | 28,500 lin. ft. | .50 | 8,000. | 6,250. | 14,250. |
| 12 A 16 | Substructure concrete | | | | | |
| 12 A 161 | Reinforced concrete walls | 1,450 cu. yds. | 40.00 | 29,000. | 29,000. | 58,000. |
| 12 A 162 | Reinforced concrete floors and footings | 1,650 cu. yds. | 20.00 | 16,500. | 16,500. | 33,000. |
| 12 A 163 | Plain concrete | 500 cu. yds. | 15.00 | 3,750. | 3,750. | 7,500. |
| | Sub-total | | | 90,140. | 82,750. | 172,890. |
| | Contingencies | | | 9,000. | 8,110. | 17,110. |
| 12 A 1 | Total sub-structure | | | 99,140. | 90,860. | 190,000. |
| 12 A 2 | POWER HOUSE SUPERSTRUCTURE | | | | | |
| 12 A 21 | STRUCTURAL STEEL | 500 tons | 120.00 | 10,000. | 50,000. | 60,000. |
| 12 A 23 | WALLS, COLUMNS, PARTITIONS AND BARRIERS | | | | | |
| 12 A 231 | Brick walls | 324 M common br. | 60.00 | 11,940. | 7,500. | 19,440. |
| | | 118 M face brick | 75.00 | 4,500. | 4,350. | 8,850. |
| 12 A 232 | Concrete | 600 cu. yds. | 35.00 | 10,500. | 10,500. | 21,000. |

ESTIMATED BY ESTIMATE APPROVED BY PAGE 1 OF 14 PAGES

FIG. 1

OFFICIAL ESTIMATE NO. DATE IMPROVEMENT REG'N NO. ENG. CONT. OR CHI. W. O.

COMPANY DIVISION WORK

| ACCOUNT | ACCOUNT NAME | QUANTITY | UNIT COST | LABOR | MATERIAL | TOTAL |
|---|---|---|---|---|---|---|
| | SUMMARY | | | | | |
| | SPECIFIC CONSTRUCTION ACCOUNTS | | | | | |
| 12 A | Power house building | | | 260,000. | 174,607. | 434,607. |
| 12 L | Yard trackage | | | 11,000. | 11,000. | 22,000. |
| 13 | Boiler plant equipment | | | 98,800. | 725,100. | 823,900. |
| 15 A | Turbo-generators | | | 4,500. | 419,550. | 424,050. |
| 15 X | Condensing system | | | 26,500. | 139,358. | 165,858. |
| 16 | Station electrical equipment | | | 62,500. | 78,765. | 141,265. |
| 28 | Substation equipment | | | 36,290. | 129,438. | 165,728. |
| | Total Specific Construction Cost | | | 499,590. | 1,677,818. | 2,177,408. |
| | TEMPORARY CLEARING ACCOUNTS | | | | | |
| A | Construction equipment | | | | | 20,000. |
| B | Local transportation | | | | | 3,000. |
| C | Temporary roads and railways | | | | | 4,000. |
| D | Temporary service facilities | | | | | 2,000. |
| E | Construction camp | | | | | 5,000. |
| F | Concrete general costs | | | | | 9,000. |
| J | Preliminary operation | | | | | 15,000. |
| K | Injuries, damages & liability insurance | | | | | 18,000. |
| | Total Cost to be Cleared to Construction Accounts | | | | | 75,000. |
| | GENERAL ACCOUNTS | | | | | |
| X 1 | Local administration | | | | | 89,800. |
| X 2 | Engineering | | | | | 168,600. |
| X 3 | Interest during construction | | | | | 44,900. |
| | Total General Cost | | | | | 303,400. |
| | GROSS CONSTRUCTION COST | | | | | 2,555,808. |

ESTIMATED BY John Jones ESTIMATE APPROVED BY W.J.White PAGE 14 OF 14 PAGES

FIG. 2

CONSTRUCTION COST REPORT COMPANY States Power Company DIVISION

| I. R. NO'S | LOCAL W. O. NO'S |
|---|---|
| 14502 | 2503 |

E.C. NO.'S, CHI. W.O. 25914 REPORT AS OF DATE April 30,1929.

WORK Additional 20,000 K. W. unit

| ACCOUNT | ACCOUNT NAME | COST TO DATE LABOR | COST TO DATE MATERIAL | COST TO DATE TOTAL | PROBABLE TOTAL COST | OFFICIAL ESTIMATE |
|---|---|---|---|---|---|---|
| 12 A | POWER HOUSE BUILDING | | | | | |
| 12 A 1 | POWER HOUSE SUBSTRUCTURE | | | | | |
| 12 A 11 | Test holes and exploration | 853.67 | 149.22 | 1,002.89 | 1,003. | 1,200. |
| 12 A 12 | Removing obstructions | 1,685.28 | 98.32 | 1,783.60 | 1,784. | 3,500. |
| 12 A 13 | Excavation | | | | | |
| 12 A 131 | Water removal | 5,582.96 | 1,187.25 | 6,770.21 | 7,350. | 6,000. |
| 12 A 132 | Shoring, bracing and wood sheet piling | 982.60 | 2,245.18 | 3,227.78 | 3,500. | 4,000. |
| 12 A 133 | Sheet steel piling | 4,368.19 | 22,675.21 | 27,043.40 | 28,000. | 25,500. |
| 12 A 134 | Earth excavation | 9,675.72 | 368.45 | 10,044.17 | 10,500. | 13,440. |
| 12 A 135 | Rock excavation | 1,964.57 | 635.64 | 2,600.21 | 3,000. | 1,750. |
| 12 A 136 | Underpinning adjacent bldg. | 3,564.19 | 2,814.63 | 6,378.82 | 7,350. | 0. |
| 12 A 14 | Backfill | 368.19 | | 368.19 | 4,500. | 4,750. |
| 12 A 15 | Bearing piling | | | | | |
| 12 A 151 | Wood piling | 5,892.17 | 6,475.18 | 12,367.35 | 14,250. | 14,250. |
| 12 A 16 | Substructure concrete | | | | | |
| 12 A 161 | Reinforced concrete walls | 25,687.42 | 2,862.47 | 28,549.89 | 58,000. | 58,000. |
| 12 A 162 | Reinforced concrete floors and footings | 12,418.67 | 15,286.45 | 27,705.12 | 33,000. | 33,000. |
| 12 A 163 | Plain concrete | 3,645.29 | 3,286.78 | 6,932.07 | 7,800. | 7,500. |
| | Sub-total | 76,688.92 | 58,084.78 | 134,773.70 | 180,037. | 172,890. |
| | Contingencies | | | | 4,500. | 17,110. |
| 12 A 1 | Total substructure | | | | 184,537. | 30,000. |
| 12 A 2 | POWER HOUSE SUPERSTRUCTURE | | | | | |
| 12 A 21 | STRUCTURAL STEEL | 1,468.22 | 46,767.86 | 48,236.08 | 60,000. | 60,000. |
| 12 A 23 | WALLS, COLUMNS, PARTITIONS AND BARRIERS | | | | | |
| 12 A 231 | Brick walls | 293.97 | 1,587.65 | 1,987.62 | 28,290. | 28,290. |

PAGE 1 OF 14 PAGES SIGNED CONST'N. AUDITOR CEN'L. SUPT. OF CONST'N.

FIG. 3

CONSTRUCTION COST REPORT COMPANY DIVISION

| I. R. NO'S | LOCAL W. O. NO'S |
|---|---|
| 14502 | 2503 |

E.C. NO.'S, CHI. W.O. 25914 REPORT AS OF DATE April 30, 1929

WORK

| ACCOUNT | ACCOUNT NAME | COST TO DATE LABOR | COST TO DATE MATERIAL | COST TO DATE TOTAL | PROBABLE TOTAL COST | OFFICIAL ESTIMATE |
|---|---|---|---|---|---|---|
| | SUMMARY | | | | | |
| | SPECIFIC CONSTRUCTION ACCOUNTS | | | | | |
| 12 A | Power house building | 220,538.35 | 147,025.37 | 367,563.92 | 445,600. | 434,607. |
| 12 L | Yard trackage | 9,383.53 | 10,043.65 | 19,427.18 | 22,000. | 22,000. |
| 13 | Boiler plant equipment | 22,567.16 | 87,276.05 | 109,843.21 | 823,900. | 823,900. |
| 15 A | Turbo-generators | 3,171.26 | 60,253.90 | 63,425.16 | 424,050. | 424,050. |
| 15 X | Condensing system | 17,789.28 | 53,786.62 | 71,575.90 | 172,000. | 165,858. |
| 16 | Station electrical equipment | 1,284.55 | 24,403.33 | 25,687.88 | 141,265. | 141,265. |
| 28 | Substation equipment | 851.47 | 26,615.27 | 27,466.74 | 155,500. | 165,728. |
| | Total Specific Construction Cost | 275,355.20 | 409,404.59 | 684,759.79 | 2,184,315. | 2,177,408. |
| | TEMPORARY CLEARING ACCOUNTS | | | | | |
| A | Construction equipment | 7,068.41 | 11,465.97 | 18,532.38 | 15,000. | 20,000. |
| B | Local transportation | 76.57 | 1,321.66 | 1,398.23 | 2,000. | 2,000. |
| C | Temporary roads and railways | 921.32 | 2,245.87 | 3,167.19 | 3,200. | 4,000. |
| D | Temporary service facilities | 256.49 | 986.24 | 1,242.73 | 2,500. | 2,000. |
| E | Construction camp | 2,365.92 | 3,184.25 | 5,550.18 | 5,000. | 5,000. |
| F | Concrete general costs | 1,325.64 | 11,367.22 | 12,692.86 | 11,000. | 9,000. |
| J | Preliminary operation prior to acceptance .00 | | 0.00 | .0.00 | 15,000. | 15,000. |
| K | Injuries, damages & liability insurance .00 | | 11,121.42 | 11,121.42 | 18,000. | 18,000. |
| | Total cost to be cleared to construction accounts | 12,014.35 | 41,690.63 | 53,704.98 | 71,700. | 75,000. |
| | GENERAL ACCOUNTS | | | | | |
| X 1 | Local administration | 22,153.14 | 7,384.38 | 29,537.52 | 89,300. | 89,900. |
| X 2 | Engineering | | 56,123.26 | 56,123.26 | 168,600. | 168,600. |
| X 3 | Interest during construction | | 8,364.22 | 8,364.22 | 35,000. | 44,900. |
| | Total General Cost | 22,153.14 | 71,871.86 | 94,025.00 | 293,500. | 303,400. |
| | GROSS CONSTRUCTION COST | 309,522.69 | 522,967.08 | 832,489.77 | 2,549,515. | 2,555,808. |

PAGE 14 OF 14 PAGES SIGNED A. B. Smith CONST'N. AUDITOR J. B. Brown CEN'L. SUPT OF CONST'N.

FIG. 4

FIGS. 1 AND 2. FIRST AND LAST PAGE OF A 14-PAGE ESTIMATE
FIGS. 3 AND 4. FIRST AND LAST PAGE OF A CORRESPONDING CONSTRUCTION COST REPORT

put it into readiness to operate. This estimate, made under the appropriate specific construction accounts, amounts to $80,000 and is recognized to be subject to a later apportionment of certain indirect charges.

These indirect costs are not estimated by the engineer but by the Construction Superintendent, who is acquainted with local conditions and who organizes his construction forces, lays out his camp, orders his construction and transportation equipment and builds certain temporary construction roads, all to serve the entire project. He makes the estimate for all of these under the proper clearing accounts but makes no attempt to apportion them in advance to this and that specific construction account.

During the progress of the work, service records are maintained for all major construction equipment, trucks and similar equipment, to serve as a basis for later apportionment of the charges to the construction accounts served. Other clearing accounts will be apportioned at the end of the job on whatever appears to be the most rational basis, as, for instance, camp and small tools on a labor basis and others on the superintendent's estimates or reports of service rendered. In the meantime, all of these indirect costs are charged to their proper clearing accounts.

### Final Costs Directly Comparable to Engineer's Estimate

At the end of the job, before the indirect costs have been cleared, the comparison of actual costs and estimates will be upon a fair basis, both for the specific construction account and for the clearing accounts. The $80,000 estimated by the engineer for the water wheel unit will be fairly comparable with the actual cost as recorded and will result in cost information for safe use in future estimates.

Let us assume, however, that there had been charged directly to this unit certain hauling costs, inspection, traveling expenses and perhaps a portion of road building costs (all quite proper for eventual apportionment) and, following a rather common practice, these charges had been buried as "Material." The record would then show the specific construction cost of the unit to be perhaps $10,000 higher than it otherwise would be, while, at the same time, the indirect costs in the clearing accounts would be understated by a like amount. Obviously, both engineer and superintendent would be supplied with erroneous cost data and would be misled in making future estimates.

Another result that the classification is designed to secure is the derivation of "Group Costs" for use in preliminary estimates made in advance of designs. This is accomplished by a sub-division of major accounts into sub-major groups of accounts each covering a well defined sub-system within the project.

For example, the major account of "Station Electrical Equipment" is subdivided into functional groups among which, selected at random, are generator leads, station bus, synchronizing system, station auxiliary system and station control system.

Sub-major accounts covering these groups are further broken down into sub-accounts which, in the case of the electrical accounts, are substantially the same for each group, namely, conduit and conductors, supporting structures and equipment (detailed). In many cases, the group costs prove to be of greater value in making new estimates than unit costs of individual items; however, both types of unit costs are derived and each has a well defined use.

When a preliminary estimate for a new project is to be made, layout sketches are prepared covering a tentative design. Detail is entirely lacking and only the main elements of the project are shown. Applicable major and sub-major accounts are taken from the standard classification of accounts and to these are applied appropriate "group costs," selected from the cost records of similar projects, with or without modification as the engineer may deem necessary for the purpose of equalizing labor costs and other factors.

This method of estimating usually proves to be sufficient for preliminary studies and leads to the adoption of a plan and authorization to proceed with detailed designs and estimates and, eventually, to the construction of the project. As design work proceeds, detailed estimates are prepared and for this purpose use is made of the detail unit costs of other projects supplemented by current quotations on equipment.

Group costs are frequently of service for other purposes. For example, a cost study of electric drive versus steam drive for station auxiliaries will be facilitated by making use of recorded group costs of each kind of installation.

### Accuracy in Estimating Is of Prime Importance

Accuracy in estimating is perhaps the chief problem confronting all engineer-contractors. This is no less true of those who are engaged mainly in designing and constructing the properties of a group of controlled public utilities. An estimate which is appreciably too high or too low will mislead the officials of the utility company in their appraisal of the economic value of the improvement to which it relates.

If, after the project has been authorized, the estimate proves to be too low, explanations are only too likely to be embarrassing to the engineer. If there is to be found any legitimate excuse for an over-run, it will usually involve the client company's demand for "extras." Obviously, the cost of work not included or implied in the estimate is not a true "over-run" although it may be the cause of an "overexpenditure."

The system provides for the separation of over-runs from costs of unauthorized work by the simple expedient of prohibiting unauthorized work. In other words, when all concerned have agreed upon an initial estimate and set of specifications, each addition to the scope of the work requires an individual estimate and the client company's formal authorization to proceed with the addition in accordance with this estimate.

In order to visualize the application of the special features of the system to which reference has been made, it may be of interest to follow the principal steps involved in a hypothetical project from its inception to its completion.

From its study of local industrial conditions, a client company concludes that prospective power requirements will necessitate a 20,000-kw. addition to its steam

plant capacity by November 1, 1929. The Byllesby Engineering and Management Corporation is called upon to collaborate with the company's officials for the purpose of more specifically determining the requirements and general features to be embodied in the design of the proposed improvement.

Work of investigation and preparation of preliminary estimates is assigned to the mechanical, electrical and structural divisions, each of these divisions being charged definitely with the duty of completing the portion of the common task that, under the existing plan of organization, comes within its jurisdiction. In due course, this results in the preparation, by each division, of a preliminary estimate arranged in accordance with the sub-major accounts only of the Standard Classification. Each estimate is accompanied by appropriate sketch designs and a "scope sheet" or brief specifications describing the features included in the estimate.

These estimates include only specific construction costs and are based largely upon "group cost" records of similar projects. They are supported by work sheets retained by the engineers for use in subsequent conferences. These divisional estimates are transmitted to the Production Division where after the addition of estimates to cover indirect and general costs, and the assigning of an estimate number, all are assembled, with sketches and scope sheets, copies being prepared for transmission to all concerned.

### Construction Authority Precedes Detailed Design

Study of this estimate may result in considerable correspondence and lead to one or more conferences between engineers and operating officials. Perhaps a revised preliminary estimate may be called for to meet, more nearly, the requirements of the operators.

When the preliminary estimate has finally been pronounced satisfactory as to scope and cost, the client company issues an "improvement requisition" calling for the construction of the project in accordance with the estimate. The Manager of Engineering and Construction of the Corporation then issues a "construction authorization" in which are named the engineers and construction superintendent to whom the work is assigned and details regarding purchases, reports, progress photographs and other matters regarding the prosecution of the work. The construction authorization assigns a number to the contract and ties the work in definitely with the estimate.

Work on the detailed designs now proceeds and a new classified estimate is prepared by each division engineer. This estimate follows the Standard Classification down to the most detailed sub-accounts. It is not merely a detailing of the preliminary estimate but is a new estimate based upon definite designs and, so far as possible, upon actual costs of equipment as purchase orders are placed.

As in the case of the preliminary estimate, the engineers include only specific construction costs. These estimates are assembled by the Production Division and a set sent to the construction superintendent who adds his estimate of indirect costs in accordance with the Standard Classification and checks the engineers' labor estimates. The estimate is then returned to the Production Division, where general costs are estimated in accordance with the Classification.

Then the whole is re-typed and provided with more detailed scope sheets or specifications and photostat copies of such key drawings as may be necessary to define fully the scope of the project. Copies are sent to all concerned. When this classified estimate, which will not agree exactly with the preliminary estimate, is approved by the operating company, it is known as the "official estimate" and will probably call for a re-issue of the "construction authorization", revising the authorized cost of the work. The first and last pages of this official estimate are illustrated in Figs. 1 and 2.

### Purchasing Tied in with Construction Schedule

Well in advance of actual construction work, conferences or correspondence between the engineers, construction superintendent, Purchasing Department and Production Division results in the establishment of schedules showing dates of beginning and completing construction work on each feature of the project, dates of delivery of corresponding material and drawings, and dates for requisitioning each class of material in order that it may be purchased and delivered in time to meet the construction schedule, all to the end that the plant may be assured of completion in readiness to operate on, but not much before, November 1, 1929, as agreed.

In connection with this scheduling every class of material required on the project is indicated on standard printed check lists.

Figure 1, the first page of a 14-page estimate on an assumed construction project, shows the substructure group of sub-major accounts. It is taken directly from the Standard Classification with merely the omission of such detail accounts as have no bearing on this particular project. On the subsequent pages of the estimate, each sub-major account—specific construction, clearing and general—is similarly treated, leading to the summary on page 14 illustrated in Fig. 2.

As construction work proceeds, cost reports are submitted regularly each month. The first and last pages of the April cost report for the project under consideration are illustrated in Figs. 3 and 4. These cover the same group of accounts as those shown on pages 1 and 14 of the official estimate illustrated in Figs. 1 and 2. Labor and material costs to April 30 for each detail account, each group of accounts and the total are shown, as well as the corresponding figures of the official estimate and, in the "probable total cost" column, the construction superintendent's revised estimate for each account.

This monthly cost report reaches the Chicago office about the middle of the month, in this case May 15, and the first thing to be examined is the last line of the report, "Gross construction cost." This shows that $832,000 has been spent to date and that the latest estimate indicates that the project will be completed within the official estimate.

Turning to the next page of the report and scrutinizing each item of the 14 pages, several matters of interest are found. The cost of "removing obstructions" was only half of the estimated figure and this part of the work has been finished as shown by the cost

to date. Several over-runs and under-runs are noted; one of them—"rock excavation"—while not large in amount, will cost nearly twice as much as estimated. One item—"underpinning adjacent building"—indicates an oversight on the part of the estimator, since it is not shown in the official estimate although it may have been included in "shoring and bracing" or "earth excavation," both of which are well within the estimate. In any event, the "contingency" allowance was more than sufficient and the substructure group as a whole is now estimated to under-run the official estimate.

### Irregularities Are Explained by Special Report

Proceeding through the remaining pages of the report, many similar items are found, some of them being of sufficient magnitude to require an explanation on the part of the construction superintendent. This explanation is found in a special report attached to the monthly cost report or mailed in advance of it.

Coming to the clearing accounts at the end of the report, the cost to date of several of these is found to be in excess of the "probable total cost" and the project is not half complete. The explanation is that these items have considerable salvage value which will later be credited to their respective accounts.

These monthly cost reports are supplemented by standard progress reports, quantity reports and weekly letters, all of which, together with the purchasing department's follow-up system, are relied upon to show at all times the status of the work, so that the date of completion agreed upon may be met.

### Additions Are Taken Care of by Special Authorization

If, during the construction period, the operating company desires to add to the scope of the work, the engineers are requested to submit an estimate on the desired addition. The procedure is practically a repetition of that connected with the main project. The estimate is made and, when approved by the operating company, is covered by an improvement requisition and a construction authorization. It then automatically becomes an addition to the "official estimate" and is thereafter shown in the "official estimate" column of the monthly cost reports, new accounts being opened for this purpose unless the new work is of such a nature that it falls within accounts already in use. In this latter case, the existing accounts are used for recording the cost of the new work, but the official estimate for these accounts is increased to include the new work.

On completion of the project, the final cost report is accompanied by a "job analysis" prepared by the construction superintendent after a prescribed fashion. These are forwarded to the production division, where cost analyses are made for the derivation of unit costs and group costs for use in future estimating. As outlined, the system is applicable mainly to major projects. For small jobs running under, say, $250,000, the procedure, while remaining the same in principle, is somewhat simplified.

In conclusion, the system of estimating and cost keeping described aims to accomplish or facilitate the following: to localize and make effective responsibility for estimates; to co-ordinate the activities of all departments concerned in the execution of a project; to give timely notice of probable over-runs; to prevent unauthorized expenditures; to derive fully defined unit costs; to provide, through standardization, for comparison of costs of different projects, and to furnish information so arranged as to be of greatest service for purposes of estimating, valuation, rate making, insurance, auditing and commission reports.

## N. D. H. A. Meets June 12-15 at Atlantic City

At the Ambassador Hotel, Atlantic City, N. J., the 19th Annual Convention of the National District Heating Association will be held June 12 to 15. On Tuesday, June 12, at 2 p. m., Charles A. Gillham, New York Steam Corp., president of the association, will open the convention. After reports from several of the committees, Walter H. Johnson, Philadelphia Electric Co., will present an address.

On Tuesday evening, reports of the committees on research and development will be presented, together with a paper by A. J. Slade of the American District Steam Co. on The Manufacturers' Division and Its Work and an illustrated lecture on District Heating Progress. Report of the operating statistics committee will be made on Wednesday at 9:30 a. m., followed by an address by H. P. Liversidge, Philadelphia Electric Co. and a paper entitled "Putting a Hot Water System in Black Ink" by Stephen Delaney of the Atlantic City Electric Co.

On Thursday at 9:30 a. m., the subject of meters and accessories and the report of rates and regulations committees will engage the attention of the meeting, while on Friday morning the station operating committee and distribution committee will present their reports, followed by election of officers.

Following each technical section, a manufacturers' round table will be held in accordance with the usual practice.

Full information about the coming convention can be obtained from D. L. Gaskill, Secretary, N. D. H. A., 603 Broadway, Greenville, Ohio.

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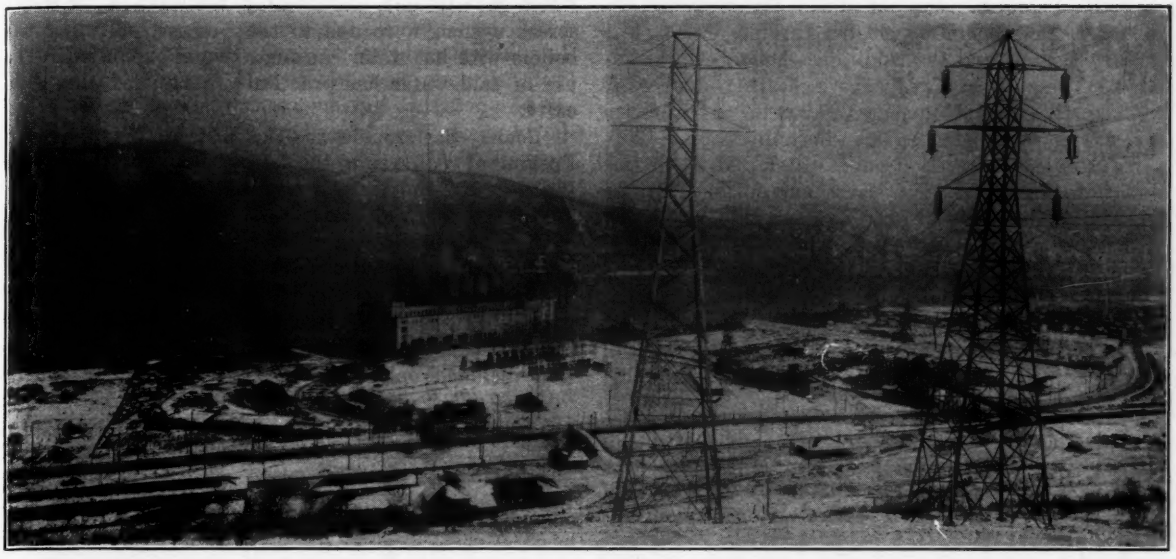
Output of electricity by public-utility power plants in the United States in 1927 was 80,205,000,000 kw-hr., according to the revised figures of the Department of the Interior, just published by the Geological Survey. The increase in output from 1926 to 1927 was about 9 per cent. The amount produced by water power was about 37 per cent of the total, as against 35½ per cent in 1926.

Net importation of electricity from Canada in 1927 was 1,629,000,000 kw-hr. The total amount of electricity from public-utility sources utilized in the United States was therefore 81,834,000,000 kw-hr. This is equivalent to 690 kw-hr. per capita. The corresponding figure for Canada in 1927 was 1320 kw-hr. per capita. and that for Norway in 1925 was 2400 kw-hr. per capita. Norway, Canada and the United States lead the world in the per capita consumption of electricity. The total output in the three countries in 1925, in billions of kilowatt-hours, was as follows: Norway, 6.7; Canada, 9.8; United States, 65.9.



# Toronto Station Doubles Generating Capacity

PERFORMANCE RECORD FOR TWO AND ONE HALF YEARS SHOWS STEADY IMPROVEMENT TO PRESENT LOW VALUE OF 15,000 B.T.U. PER KW. SENDOUT. BY G. S. COFFIN

IN JUNE, 1925, the first section of the Ohio River Edison Co., Toronto Station, was put in service, in 1927 the first extension was added and the second extension is scheduled for completion in September, 1928. This station, designed and constructed by Stevens & Wood, Inc., to serve the Penn-Ohio system in the territory surrounding Youngstown, Ohio and Sharon, Pa., is located on the Ohio River near Steubenville, Ohio, about 40 mi. from the load center and the entire output is delivered over 132,000-v. transmission lines to the Boardman substation near Youngstown for distribution. Lack of condenser water in the Youngstown district was the controlling factor in the selection of the station site, although cheap river coal and extensive coal fields adjacent to the present location were important factors.

G. S. COFFIN, mechanical engineer with Stevens & Wood, Inc., was born in Charleston, S. C., and graduated from Cornell University in 1912 with the degree of mechanical engineer.

Since graduation he has been successively: Assistant engineer, Bureau Public Buildings and Offices, New York; engineer, Remington Arms U-M-C Co., Bridgeport; plant engineer, Bayles Shipyard, Inc., Port Jefferson, Long Island; mechanical engineer, U. S. Shipping Board, North Atlantic District; mechanical engineer, Crosby Steam Gage & Valve Co., Boston; and mechanical engineer with Stevens & Wood since 1923.

Two boilers, with an operating steam pressure of 400 lb. gage at the boiler drums, are provided for each main turbine unit, steam conditions being 350 lb. 700 deg. F. at the turbine throttle valves. The regenerative cycle with three-stage extraction from the main unit is used with two additional extraction points provided on the auxiliary turbine, to maintain automatically a constant feedwater temperature of 370 deg. F. at all loads.

Because of the high feedwater temperature, air preheaters were selected instead of economizers, secondary air being heated to 275 deg. F. for the first four boiler units and to 450 deg. F. for the last four boiler units. Both evaporators and deaerator units are installed directly in the heating cycle of each main unit, as shown in Fig. 3, the heat balance of the last section. This heat balance differs little from that of the original section or the 1927 extension.

Two 33,000-kw. main units with two 1500-kw. auxiliary turbines were installed in the first section. Four boilers with a heating surface of 20,470 sq. ft. (normal capacity 210,000 lb. of steam per hr.), water walls and water screens, a 4100-sq. ft. interdeck convection superheater and a furnace volume of 13,500 cu. ft. above the water screen were provided to serve them with steam. The bin type pulverized fuel system was used, with one 15-t. mill for each boiler unit. The output of each mill normally discharging directly into the pulverized coal bin serving one boiler, although screw conveyors permit transferring pulverized coal from any mill to any bin.

## FIRST EXTENSION ADDED IN 1927

In 1927, the first extension was completed, increasing the capacity of the station 33,000 kw. The auxiliary turbine for this unit is a 2000-kw. machine, and the two boilers with a total heating surface of 21,620 sq. ft. each (normal capacity 300,000 lb. of steam per hour), water cooled walls and ashpit floors, a 3545-sq. ft. interdeck convection superheater and a furnace volume of 18,000 cu. ft. are also fired by pulverized coal from individual bins, each bin served by one 15-t. mill.

In the 1928 extension scheduled for operation in September, the fourth 33,000-kw. turbine, a 2000-kw. auxiliary turbine and two additional boilers will be installed. These boilers will have a heating surface of 20,468 sq. ft. (normal capacity 300,000 lb. of steam per hour), water cooled side walls and ashpit floors, a 4250-sq. ft. interdeck convection superheater and a furnace volume of 17,000 cu. ft. Details and changes in the furnace design are shown in Fig. 6. In this section the unit system, without coal dryers, will be used, with two 10-t. mills serving each boiler. The general arrangement of the equipment in this section is shown in Fig. 4.

Many new power plant developments have occurred since the preliminary designs were completed in 1923, nevertheless the equipment and design are in close accord with best modern practice and two-and-a-half years' operation have demonstrated their ability to produce power in a creditable manner. Performance of the station has been satisfactory. Figure 1, and the table give the principal performance data from July, 1925, when the station was put in commercial operation, to December, 1927. The thermal efficiency has increased steadily, until it is now about 23 per cent, equivalent to a performance of about 15,000 B.t.u. per kw. sendout during the winter season.

Although the performance has been satisfactory and the station put into operation without serious difficulty, minor troubles have been experienced. The first difficulty was with the superheaters. Low superheat, excessive pressure drop and tube failure because of improper steam distribution were problems that had to be solved by changing ferrules and baffles. Leaks at the joints in the circulating system for the water screens were finally prevented by using metal gaskets and providing additional spring supports. Leaking boiler tubes, which gave trouble, and possibly, the leaks in the water screen system were due to the practice of filling the boilers with hot water causing unequal expansion. The use of cold water has practically eliminated this difficulty.

Coal feeder trouble was experienced from the start. Packing of coal around the feeder screws, arching above the feeders and excessive wear caused considerable annoyance and high maintenance. These troubles, combined with wear on mill exhauster fans and minor electrical troubles caused a much larger boiler outage than had been expected so that at times the maximum output of the station could not be maintained. Pulverizer capacity was another limitation. The original installation included only three 15-t. mills for four boilers.

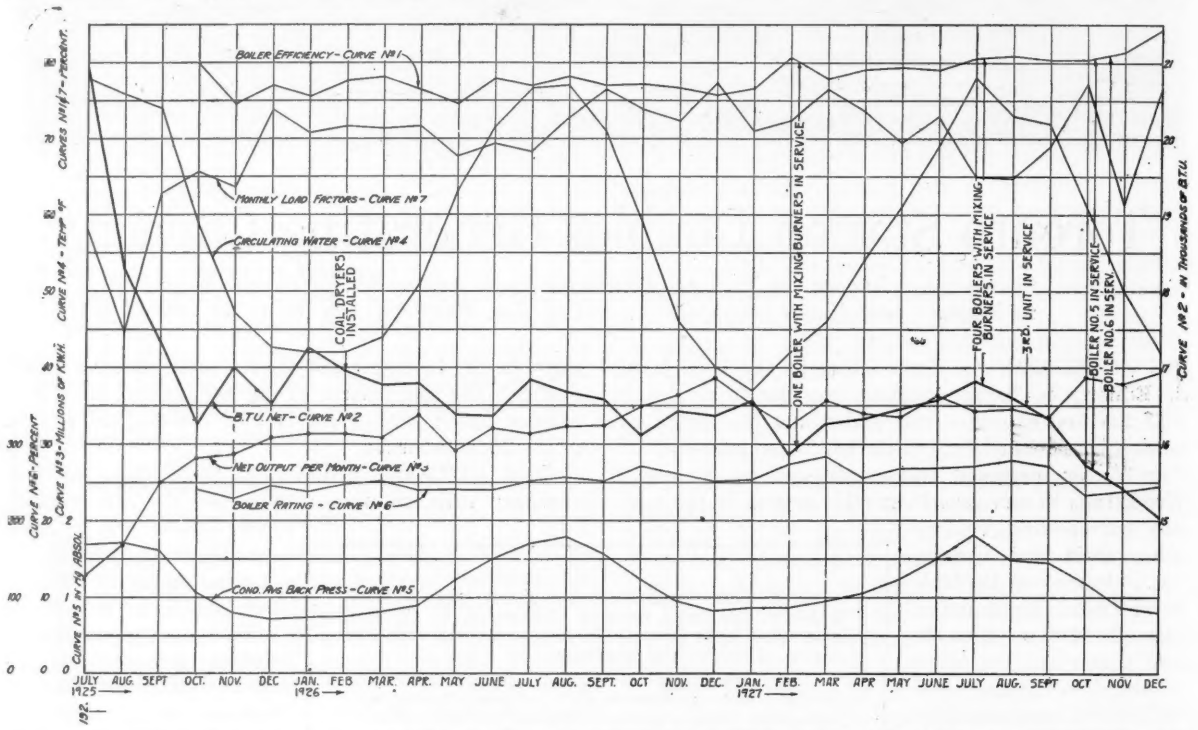

BOILER EFFICIENCY - CURVE No 1
MONTHLY LOAD FACTORS - CURVE No 7
CIRCULATING WATER - CURVE No 4
COAL DRYERS INSTALLED
B.T.U. NET - CURVE No 2
NET OUTPUT PER MONTH - CURVE No 3
BOILER RATING - CURVE No 6
COND. AVG. BACK PRESS. - CURVE No 5
ONE BOILER WITH MIXING BURNERS IN SERVICE
FOUR BOILERS WITH MIXING BURNERS IN SERVICE
3RD. UNIT IN SERVICE
BOILER NO. 5 IN SERVICE
BOILER NO. 6 IN SERV.
CURVES Nos 1 & 7 - PERCENT
CURVE No 4 - TEMP °F
CURVE No 3 - MILLIONS OF K.W.H.
CURVE No 6 - PERCENT
CURVE No 5 - IN HG. ABSOL.
CURVE No 2 - IN THOUSANDS OF B.T.U.
JULY AUG. SEPT OCT. NOV. DEC JAN. FEB MAR APR. MAY JUNE JULY AUG. SEPT OCT NOV. DEC. JAN. FEB. MAR APR MAY JUNE JULY AUG. SEPT OCT NOV DEC.
1925
1926
1927
192-

FIG. 1. PERFORMANCE DATA OF TORONTO STATION PLOTTED BY MONTHS FROM JUNE, 1925, TO DECEMBER, 1927

Extremely poor coal and excessive moisture reduced the capacity of the mills below 12 t. per hr. each, while high maintenance further reduced the daily output.

### Coal Dryers Were Added in 1926

It was soon evident that dry coal was essential and immediate steps were taken to provide dryers. The fourth pulverizer, along with four grid type steam dryers, was put in service early in 1926. Much of the coal burned was from a mine near the plant, and contained at times large quantities of clay and slate which effectively plugged the openings in the dryer grids. Therefore, one dryer unit was replaced with a rotary steam type and, while experiments were being made with this unit, two flue gas dryers were installed. Boiler units No. 5 and 6 were equipped with rotary type dryers and since that time the remaining grid dryer has also been replaced by the rotary type, so that the station now contains four rotary steam dryers and two flue gas dryers. All are reasonably effective

but there is room for improvement, particularly in the flue gas type.

During this time, the load on the station was gradually increasing and it was apparent that full load could not be carried without making excessive and objectionable smoke. Poor feeding of coal, coarse grinding, lack of fan capacity and operating methods were all blamed for this condition. New feeders and burners did not solve the difficulties and forced draft burners and various schemes for air distribution were tried without appreciable effect. The real trouble unquestionably lies in the original design. The furnaces contain 13,500 cu. ft. of effective combustion space and, in order to carry the full load on the station, a heat liberation in the furnace approaching 26,000 B.t.u. per cu. ft. per hr. is required. The type of burner and furnace arrangement originally installed is shown at the left of Fig. 6. The performance might have been better with a deeper furnace, but it is extremely doubtful if this type of firing will operate at this high rating without smoke, even though it has proved effective at lower rates of combustion.

During 1926 and 1927, experiments were made with a mixing type of forced draft burner. The manufacturer first offered a standard burner but the large numbe required and the high secondary air pressure were objectionable, so that a special burner of high capacity was designed and tried out. The results of this experiment led to equipping one boiler with six mixing burners for horizontal firing. This required rebuilding the front wall and lining the hollow walls with sheet metal to transmit the higher pressure secondary air. This arrangement proved effective in reducing smoke and permitting operation at higher ratings than had been obtained previously. In fact, this boiler, when equipped with a large induced draft fan, developed 325,000 lb. of steam per hour without objectionable smoke. Arranged for vertical firing, the boilers were limited to 180,000 lb. of steam per hr. without smoke, although with dense black smoke 250,000 lb. had been produced. The experience with this boiler resulted in equipping

FIG. 2. TURBINE ROOM OF TORONTO STATION SHOWING THE ABSENCE OF A PARTY WALL BETWEEN THE TURBINE ROOM AND BOILER ROOM

all four of the original boilers with horizontal mixing furnace equipment of the first two sections is shown in burners and the present arrangement of burner and the second section of Fig. 6.

### Individual Boiler Capacity Increased for Extension

During this period, furnace equipment for the 1927 extension was selected. Bailey furnaces with Calumet type burners were decided on and the two boilers, of which the right-hand illustration in Fig. 6 shows a typical cross section, were put in service in October, 1927. In order to make up for any possible deficiency in the old boilers, the new equipment was purchased for a maximum 350,000 lb. of steam per hr. instead of 280,000 lb. per hr. provided for originally.

In the fall of 1927, immediately after the third main unit was put in service, No. 1 main unit was taken out of service for general inspection and overhauling. Cracked blades in the last wheel were discovered and, as soon as repairs were made, No. 2 unit was taken out of service for the same reason; therefore, except for a

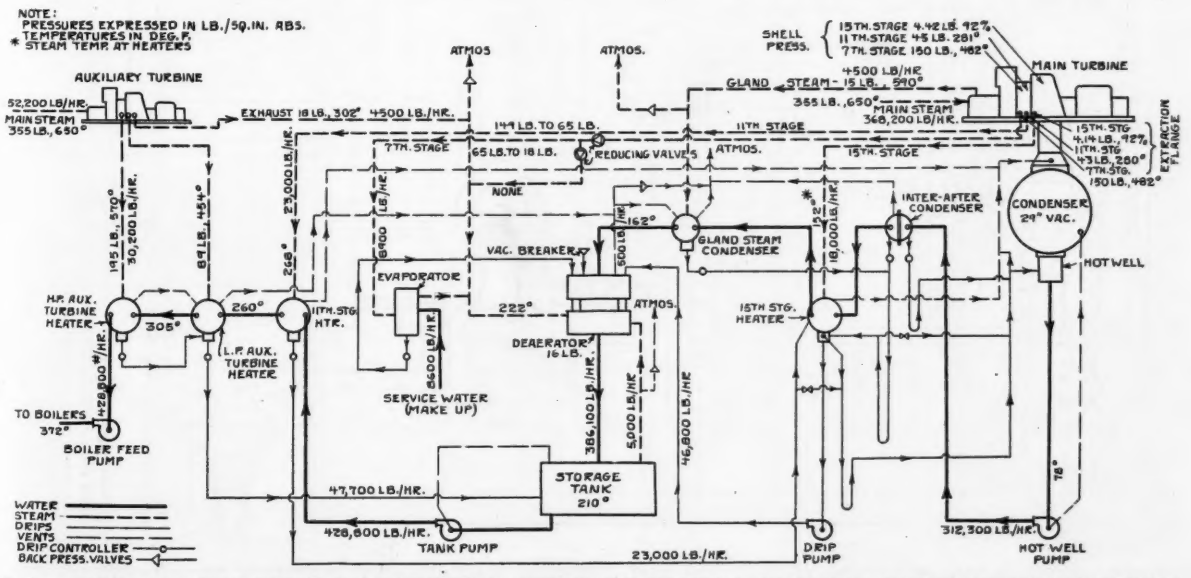



FIG. 3. HEAT BALANCE OF THE 1928 EXTENSION DIFFERS BUT SLIGHTLY FROM THAT OF THE OTHER TWO SECTIONS

TABULATED OPERATING DATA OF TORONTO STATION FROM THE DATE IT WAS PUT INTO SERVICE THROUGH 1927

| | 1925 | 1926 | 1927 |
|---|---|---|---|
| | 6 Months Only | 12 Months | 12 Months |
| 1. Net generated kw. hrs. | 142,198,800 | 395,096,146 | 425,148,440 |
| 2. Station use, per cent | 6.76 | 6.04 | 6.23 |
| 3. Maximum hour, kw. | 66,700 | 71,900 | 79,500 |
| 4. Annual load factor, per cent | 51.9 | 66.8 | 65.3 |
| 5. Max. monthly load factor, per cent | 73.9 | 77.4 | 77.4 |
| 6. Capacity installed (main units) kw. | 70,000 | 70,000 | 70,000 |
| 7. Annual capacity factor, per cent | 48.1 | 66.7 | 72 |
| 8. Net B.t.u. per kw. hr. | 17,722 | 14,582 | 14,194 |
| 9. Net station thermal efficiency, per cent | 19.4 | 20.6 | 21.1 |
| 10. Make-up fed to boilers, per cent | 2.16 | 1.7 | 1.85 |
| 11. Aver. main unit water rate, lb.per kw.hr. | 10.76 | 10.15 | 9.95 |
| 12. Net station water rate, lb. per kw. hr. | 13.72 | 12.45 | 12.65 |
| 13. Aver. steam pressure at turbine, lb. gage | 351 | 348 | 352 |
| 14. Aver. steam temperature at turbine, deg. F | 631 | 659 | 673 |
| 15. Aver. condenser absolute pressure, in. Hg. | 1.26 | 1.16 | 1.17 |
| 16. Inlet condensing water temperature, deg. F | 63 | 57 | 57 |
| 17. Max. circulating water temperature, deg. F | 82 | 82 | 81 |
| 18. Aver. boiler feed temperature, deg. F | 323 | 343 | 340 |
| 19. Aver. boiler rating, per cent | 239 | 284 | 261 |
| 20. Aver. hourly generation per boiler, lb. | 188,000 | 187,000 | 192,000 |
| 21. B.t.u. added at boiler per lb. of steam | 1,036 | 1,011 | 1,041 |
| 22. Aver. temperature air to preheaters, deg.F | | 103 | 98 |
| 23. Aver. temperature air from preheaters, " " | | 285 | 311 |
| 24. Lb. coal per net kw. hr. | 1.37 | 1.30 | 1.32 |
| 25. Aver. boiler efficiency, per cent | 77.1 | 77.1 | 79.8 |
| AVERAGE COAL ANALYSIS (BUNKER) | | | |
| 26. Moisture, per cent | 4.16 | 4.53 | 5.24 |
| 27. Volatile, per cent | 35.76 | 37.65 | 39.19 |
| 28. Carbon, per cent | 54.43 | 52.30 | 49.55 |
| 29. Ash, per cent | 9.81 | 10.05 | 11.26 |
| 30. Sulphur, per cent | 2.54 | 2.48 | 3.46 |
| 31. B.t.u. per lb. as received | 12,927 | 12,808 | 12,305 |
| 32. Approx. fusing temperature of ash, deg. F | | | 1,950 |

short period, only two units were available until the end of 1927. The result is apparent in the performance data. A lower heat rate occurred at the end of the year, due to the change in method of firing and to the greater boiler capacity available with only two main units running.

Conditions during the present year will be more nearly typical as three main units are now in service. Higher output with lower boiler efficiency may adversely affect the thermal performance but a considerable improvement over 1927 is expected. The new boilers have not been pushed to high rating and continuous service has not been demanded of them. No serious combustion difficulties are expected, as the furnaces contain 18,000 cu. ft. of combustion space and the B.t.u. liberation will not exceed 25,000 B.t.u. per cu. ft. at maximum rating. Considerable difficulty, however, has already been experienced with ash removal. The ash is largely molten and at first solidified in the ashpit. Water sprays were added to chill and break up the molten slag and are partially effective; however, excessive labor is still required to remove the ash and prevent its building up on the furnace floors.

Among the minor difficulties which have been met are excessive wear on induced draft fans and mill exhauster blades, erosion of boiler feed pump glands and high-pressure steam valve leakage. No satisfactory method of preventing fan blade wear has been found but the new induced draft fans are of the plate type and somewhat lower maintenance costs are expected. Stainless steel stuffing box glands are proving superior to bronze in the boiler feed pumps and experiments are now being conducted to determine the most durable gate valve trim for high temperature service.

A few water wall and water screen tubes have failed, but the number has not been excessive. Most of the failures were due to scale deposited in the first few months of operation. The refractory furnaces have been generally satisfactory, although slagging on the front wall and failures of arch tile have occurred. The use of variable speed alternating current motors has not been entirely satisfactory in the case of the original coal feeder motors because of the variable load imposed,

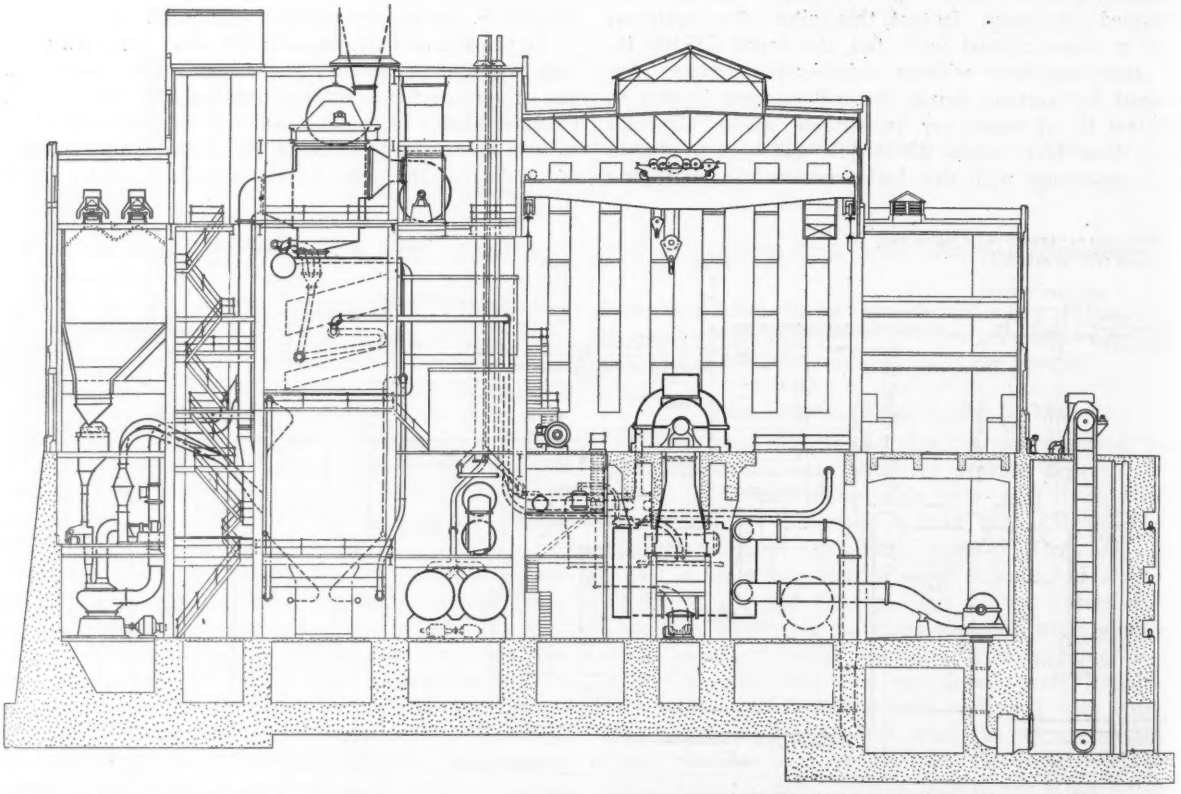


FIG. 4. A CROSS SECTION OF TORONTO STATION THROUGH 1928 EXTENSION

and on the four original boilers, the motors have all been replaced by steam turbines with excellent results.

In spite of these difficulties, the station has operated continuously and maintained a high rate of output. The performance has been creditable both to the manufacturers of equipment and to the operators and the ability to operate the boilers continuously at high ratings as shown in Fig. 1 is of particular interest. The cost of producing power is extremely low and fully justifies the selection of equipment and the basic plant design. With these changes now completed it is anticipated that the operation will be simplified and that the operating cost will show further improvement.

### General Design Features of Station

A review of some of the general features of the station will be of interest. The coal handling equipment is designed to handle the daily requirements within an 8-hr. period of time when operating six days a week. The initial installation is for 250 t. per hr., but will ultimately be doubled. Coal may be received by river or rail shipment delivering to the boiler house bunkers, open storage area, or to both at the same time. River shipment of coal is unloaded by a one-man controlled grab bucket hoisting tower shown in Fig. 5. A record of coal burned is available from weightometer readings of coal to the bunkers, as well as from the automatic scales at the pulverizer feeders. The open storage area, visible in the headpiece, is 600 ft. wide and 720 ft. long and is entirely surrounded with a berm which permits flooding to a depth of 10 ft. Coal is stored and reclaimed by a 750-ft. span movable cableway with one man control and a reversible conveying belt with movable stocking and reclaiming tripper as shown in Fig. 7.

Complete operation of coal handling equipment is

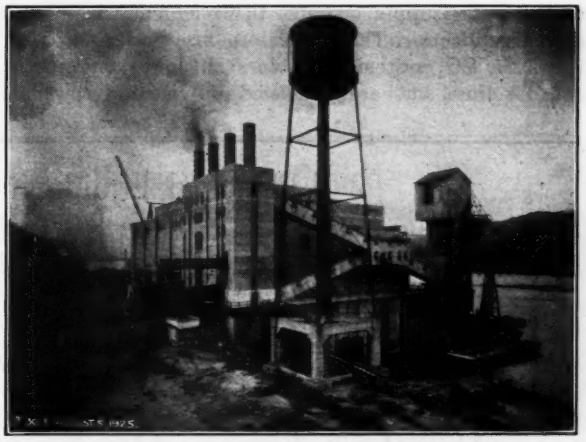


FIG. 5. RIVER COAL IS HANDLED BY A TOWER AT THE RATE OF 400 T. PER HR.

accomplished by a force of eight men. The cost of operating the entire coal handling plant on the basis of the tons of coal burned is 4.5 cents for labor; 2.6 cents for maintenance and 0.54 cents for power, making a total of 7.64 cents per t. delivered into the bunkers.

The station substructure is designed to withstand river flood conditions 40 ft. above the normal level. The cellular construction provides convenient space for the condensing water intake wells with discharge tunnel, filter and other facilities. There are no interior walls, except those surrounding the electrical control room, the offices and locker rooms. The absence of the party wall between the turbine and boiler room is plainly shown in Fig. 2.

Main generators are equipped with a closed air system cooled by surface coolers using river water. Failure

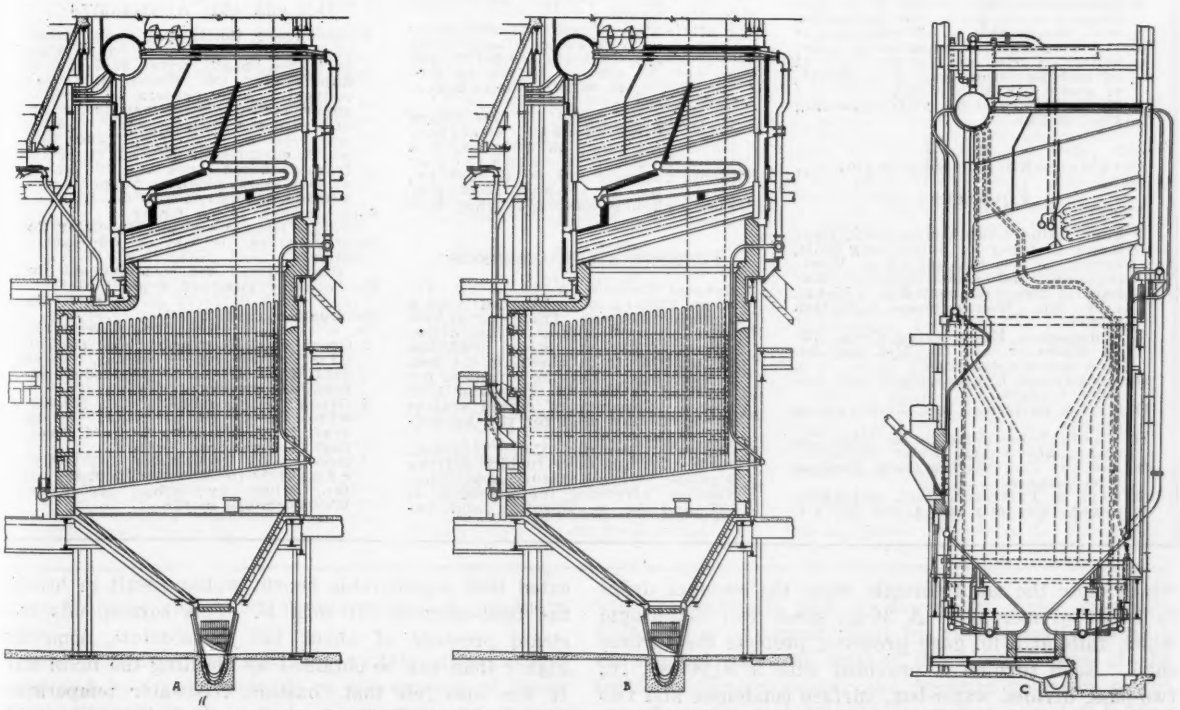


FIG. 6. DETAILS OF FURNACE CONSTRUCTION SHOWING THE DIFFERENCE BETWEEN THE ORIGINAL SECTION AS BUILT (6A), THE 1927 EXTENSION AS THEY ARE AT PRESENT (6B) AND THE 1928 EXTENSION (6C)

of the water supply operates the emergency inlet and discharge doors. The generators are protected from fire by a $CO_2$ system. Turbines have no atmospheric exhaust lines but are protected by vacuum trippers which close the main throttle when the vacuum drops to 18 in. of mercury. A 36-in. sheet lead diaphragm which fails at 5 lb. gage pressure, protects the turbine shell. Each turbine is provided with a 50,000-sq. ft., two-pass, divided water-box, surface condenser and two 30,000-g.p.m. circulating pumps driven by two-speed motors. Steam jet vacuum pumps are used for all condensers.

Because of its obvious thermal advantages, the regenerative cycle was adopted and investigation indicated that considerable benefit would result in heating the feedwater to 370 deg. F. This corresponds to a steam pressure of about 196 lb. absolute, somewhat higher than can be obtained by bleeding the main unit. It was also felt that constant feedwater temperature independent of the load on the main unit was desirable

## Principal Equipment for Toronto Station

### General

Location ..... Toronto, Ohio, on the Ohio River
Service .. Central Station Light & Power Company ..... Ohio River Edison Co.
Engineers and Constructors ..... Stevens & Wood, Inc.
Capacity—Ultimate ..... 264,000 kw.
Installed (1928) ..... 132,000 kw.
Original section ..... 66,000 kw.
1927 extension ..... 33,000 kw.
1928 extension ..... 33,000 kw.

### ORIGINAL SECTION

#### Boilers and Auxiliaries

4 Babcock & Wilcox Co., cross drum, 20,470 sq. ft. boilers, 39 tubes wide and 20 tubes high with a 4100-sq. ft. interdeck convection superheater, designed to superheat at normal full load 210,000 lb. of 375 lb. gage steam per hr. 265 deg. F. Water screen surface 2100 sq. ft. Furnace volume 13,500 cu. ft. above the water screens. Boiler setting of hollow wall special tile construction.
Soot blowers, 20 per boiler ..... Diamond Power Specialty Co.
Safety valves, 9 per boiler ..... Consolidated Ashcroft Hancock Co.
Feedwater regulators, 1 per boiler ..... Stets Co.
Combustion control ..... Smoot Engineering Co.
4 Green Fuel Economizer Co., 129,000-c.f.m. at 3.3 in. of water, induced draft fans, driven by 150-hp., 720-r.p.m. Westinghouse motors.
4 Green Fuel Economizer Co., 99,000-c.f.m. at 6 in. of water, forced draft fans, driven by 150-hp., 720-r.p.m. Westinghouse motors.
4 B. F. Sturtevant Co., 10,000-c.f.m. at 15 in. of water, primary air fans, driven by 75-hp., 1800-r.p.m. Westinghouse motors.
4 Combustion Engineering Corp. stationary steel plate air preheaters with one section of 120 elements or 11,600 sq. ft. of heating surface per boiler. Outlet air temperature at normal maximum load of 225,000 lb. of steam per hr., 260 deg. F.
4 M. H. Treadwell Co. self-supporting steel stacks.

#### Coal and Ash Handling Equipment

4 Combustion Engineering Corp., Raymond, 15-t. per hr. pulverizing mills, driven by 200-hp., 435-r.p.m. Westinghouse induction motors. Exhauster direct connected to a 75-hp., 1160-r.p.m. Westinghouse induction motor.
2 Combustion Engineering Corp., 12-in. diameter, 140 ft., 25-t. per hr. long screw conveyors.
36 Combustion Engineering Corp., Lopulco feeders.
12 Heyl & Patterson, Inc., double screw feeders.
4 Westinghouse Electric & Mfg. Co., 50-hp., 6600-r.p.m. feeder turbines.
24 Peabody Engineering Corp. Toronto type burners.
1 Heyl & Patterson, Inc., unloading tower. Capacity, 250 t. per hr., 4-t. bucket, two-drum electric hoist, driven by 200-hp. Westinghouse slip ring motor. Rack engine driven by 75-hp. Westinghouse slip ring motor. Electric barge shifter driven by 35-hp. Westinghouse slip ring motor.
1 Lidgerwood Mfg. Co. cableway roll crushers and 36-in. belt conveyors.
4 Combustion Engineering Corp. rotary type, 15-t. per hr. steam dryers.
2 Heyl & Patterson 2-section, 15-t. per hr. stationary waste heat coal dryers.
8 Richardson Scale Co., 7½-t. per hr. automatic scales.
8 Allen-Sherman-Hoff Co. ash gates.
1 Allen-Sherman-Hoff, 25-t. per hr. hydraulic ash sluice.
2 Manistee Iron Works, 1000-g.p.m. centrifugal sluice pumps.
2 Morris Machine Wks., 6-in., 1000-g.p.m. centrifugal ash pumps.
8 Dings Magnetic Separator Co. magnetic separators.

#### Boiler Feed System

2 Cochrane Corp., 1600-sq. ft. fifteenth-stage heaters.
2 Cochrane Corp., 400-sq. ft. gland steam condensers.
2 Elliott Co., open-heater, double-chamber type deaerators.
4 Standard Boiler & Plate Iron Works 20,000-gal. storage tanks.
2 Wheeler Condenser & Engineering Co., 460-sq. ft., single-effect evaporators, maximum capacity of 12,000 lb. per hr. each.
2 Cochrane Corp., 1300-sq. ft. eleventh-stage heaters.
2 Griscom-Russell Co., 640-sq. ft., auxiliary turbine low-pressure heaters.
2 Griscom-Russell Co., 1710-sq. ft. auxiliary turbine high-pressure heaters.
3 Worthington Pump & Machinery Corp., 6-in., 3-stage centrifugal tank pumps.
3 Worthington Pump & Machinery Corp., 6-in., 2-stage centrifugal booster pumps.
3 Worthington Pump & Machinery Corp., 6-in., 4-stage cenrifugal boiler feed pumps, capacity 500,000 lb. per hr. each at 470 lb. Driven by 300-hp., 1750-r.p.m. Westinghouse induction motors.
1 Worthington Pump & Machinery Corp., 6-in., 4-stage emergency boiler feed pump in series with a 10-in., single-stage centrifugal pump, capacity 503,000 lb. per hr., driven by a 417-hp., 1900-r.p.m. Westinghouse non-condensing turbine.

#### Turbines and Condensers

2 General Electric Co., 33,000-kw., 17-stage, 1800-r.p.m. turbines, driving a 3-phase, 60-cycle, 11,000-v., 37,500-kv.a. generator and a 160-kw. direct connected exciter. Steam condition at throttle 365 lb. absolute, 214 deg. F. superheat. Turbine arranged for bleeding at the 7th, 11th and 15th stages. Capacity of closed system of ventilation used for the generator, 90,000 c.f.m.
2 General Electric Co., 1500-kw., 3600-r.p.m. auxiliary turbine driving 3-phase, 60-cycle, 2300-v. generator. Turbine arranged for bleeding at 195 and 50 lb. absolute and exhausting at 18 lb. absolute.
2 Worthington Pump & Machinery Corp., horizontal, two-pass, divided water box, surface condensers, tube surface of 50,000 sq. ft., made up of 9450 1-in. o. d. Admiralty metal tubes, 20 ft. 2⅝ in. long. Tubes furnished by Bridgeport Brass Co.
4 Worthington Pump & Machinery Corp., 30,000-g.p.m., 30-in. centrifugal circulating pumps, driven by 200-hp., 2-speed motors.
4 Worthington Pump & Machinery Corp., 750-g.p.m., 6-in., centrifugal hotwell pumps, driven by 50-hp. motors.
6 Worthington Pump & Machinery Corp., 2-stage air ejectors; capacity per condenser, 70 cu. ft. of free, dry air per min.

#### Miscellaneous

4 Chain Belt Co., 7-ft. by 53-ft. traveling screens.
1 Manistee Iron Works, 500-g.p.m. centrifugal screen washer pump.
3 Manistee Iron Works, 1800-g.p.m., single-stage, centrifugal raw water pumps.
2 Manistee Iron Works, 1800-g.p.m., single-stage, centrifugal service water pumps.
1 Manistee Iron Works, 4500-g.p.m., single-stage centrifugal filter wash water pump.
2 Manistee Iron Works, 1800-g.p.m., single-stage centrifugal drainage pumps.
1 Roberts Filter Mfg. Co., 1800-g.p.m. gravity filter.
1 Morgan Engineering Co., 100-t. crane.
1 Green Fuel Economizer Co., 50,000-c.f.m. motor ventilation system.

### 1927 EXTENSION

#### Boilers and Auxiliaries

2 Springfield Boiler Co., cross drum, 21,640-sq. ft. boilers, 43 tubes wide, 26 tubes high, with 3545-sq. ft. Superheater Co. Elesco interdeck convection superheaters, designed to superheat at normal load 300,000 lb. of steam per hr., 265 deg. F. Bailey water-cooled side, front and rear walls, comprising 2578 sq. ft. of refractory faced block and 706 sq. ft. of bare metal block on hopper floors. Furnace volume, 18,000 cu. ft.
Soot blowers, 20 per boiler ..... Diamond Power Specialty Co.
Safety valves, 10 valves on each boiler ..... Consolidated Ashcroft-Hancock Co.
Feedwater regulators, 2 per boiler ..... Stets Co.
Combustion control ..... Smoot Engineering Co.
2 Green Fuel Economizer Co., 160,000-c.f.m. at 8.3 in. of water, forced draft fans, driven by 2-speed Westinghouse motors.
2 Green Fuel Economizer Co., 108,000-c.f.m. at 8.7 in. of water, forced draft fans, driven by 2-speed Westinghouse motors.
1 Green Fuel Economizer Co., 18,000-c.f.m. at 12 in. of water, primary air fan, driven by 75-hp., 1200-r.p.m. Westinghouse motor.

and some means of obtaining major auxiliary service in case of line disturbance was essential. Bleeder type auxiliary turbines operating in conjunction with the main units were therefore installed, each machine delivering to the 13,200-volt bus. Auxiliaries are then supplied through house transformers, which also supply the minor auxiliaries. Should the main power supply fail, the breaker tying the auxiliary and main units together will open and the house turbine

## Principal Equipment for Toronto Station – Continued

2 Combustion Engineering Corp., stationary steel plate air preheaters, 2 sections of 113 elements, or 32,600 sq. ft. heating surface per boiler. Outlet air temperature at normal maximum load of 300,000 lb. of steam per hr., 500 deg. F.
2 Meehan Boiler & Construction Co., self-supporting steel stacks.

### Coal and Ash Handling Equipment

2 Combustion Engineering Corp., 15-t. per hr., Raymond mills, driven by 200-hp., 450-r.p.m. Westinghouse induction motors, exhauster driven by a 100-hp., 1200-r.p.m. Westinghouse induction motor.
2 Combustion Engineering Corp., 12-in., 25-t. per hr. screw conveyors, 70 ft. long.
10 Fuller Lehigh Co., motor-driven metering feeders, supplying one Calumet type intertube burner.
2 Combustion Engineering Corp., 7½-t. per hr., rotary steam dryers.
4 Richardson Scale Co., 7½-t. per hr. automatic scales.
4 Dings Magnetic Separator Co. magnetic separators.
1 Allen-Sherman-Hoff Co. ash sluice.
6 Allen-Sherman-Hoff Co. ash gates.

### Boiler Feed System

1 Elliott Co., 1700-sq. ft., fifteenth-stage heater.
1 Elliott Co., 410-sq. ft. gland steam condenser.
1 Elliott Co., open-heater, double-chamber type deaerator.
2 Youngstown Boiler & Tank Co., 20,000-gal. storage tank.
1 Bethlehem Shipbuilding Corp., 300-sq. ft. submerged coil, Weir type, single-effect evaporator, capacity of 12,000 lb. per hr.
1 Elliott Co., 1700-sq. ft., eleventh-stage heater.
1 Elliott Co., 1600-sq. ft. auxiliary turbine low-pressure heater.
1 Elliott Co., 2000-sq. ft. auxiliary turbine high-pressure heater.
1 Worthington Pump & Machinery Corp., 105-g.p.m., fifteenth-stage drip pump.
2 Ingersoll-Rand Co., 1000-g.p.m., 6-in., 3-stage centrifugal tank pumps.
2 Ingersoll-Rand Co., 1000-g.p.m., 6-in., 3-stage centrifugal boiler feed pumps.

### Turbines and Auxiliaries

1 General Electric Co., 33,000-kw., 17-stage, 1800-r.p.m. turbine, driving a 3-phase, 60-cycle, 11,500-v., 37,500-kv.a. generator and a 175-kw., 250-v. direct connected exciter. Turbine arranged for bleeding at stages 7, 11 and 15. The generator cooled by closed system, with a capacity of 85,000 c.f.m.
1 General Electric Co., 2000-kw., 3600-r.p.m. auxiliary turbine, driving 3-phase, 60-cycle, 2300-v. generator. Turbine arranged for bleeding at 195 and 90 lb. absolute and exhausting at 18 lb. absolute.
1 C. H. Wheeler Mfg. Co., two-pass, horizontal, divided water box surface condenser with surface of 50,000 sq. ft., made up of 9570 1-in. o. d., 20 ft. 2⅝-in. long Admiralty metal tubes furnished by the Bridgeport Brass Co.
2 C. H. Wheeler Mfg. Co., 36-in., 30,000-g.p.m., centrifugal circulating pumps, driven by 135-hp., 300 and 237-r.p.m. Westinghouse 2-speed motors.
2 C. H. Wheeler Mfg. Co., 6-in., 760-g.p.m., 2-stage, centrifugal hotwell pumps, driven by 40-hp., 1200-r.p.m. Westinghouse motors.
4 C. H. Wheeler Mfg. Co., 2-stage Radojets, total capacity 92 c.f.m.

### Miscellaneous

2 Chain Belt Co. Rex vertical traveling screens, 7 ft. wide, 52 ft. high.
1 Manistee Iron Works, 6-in., 1000-g.p.m., single-stage centrifugal raw water pump.
2 Worthington Pump & Machinery Corp., 2-in., 100-g.p.m., centrifugal gland seal pumps.

## 1928 EXTENSION

### Boilers and Auxiliaries

2 Babcock & Wilcox Co., cross-drum, 20,406-sq. ft. boilers, 39 tubes wide and 20 tubes high, and with a 4260-sq. ft. interdeck convection superheater designed to superheat at normal maximum load 300,000 lb. of steam per hr., 275 deg. F. Side, front and rear furnace walls, Bailey water-cooled type, totaling 2355 sq. ft. of refractory faced block and 792 sq. ft. of bare metal block on the hopper floors. Furnace volume, 17,000 cu. ft.
Soot blowers, 20 per boiler.....Diamond Power Specialty Co.
Safety valves, 7 per boiler.....Crosby Steam Gauge & Valve Co.
Feedwater regulators, 2 per boiler.....Stets Co.
Combustion control.....Smoot Engineering Co.
2 Green Fuel Economizer Co., 160,600-c.f.m. at 8.3 in. of water, induced draft fans, driven by 720 and 515-r.p.m., 2-speed Westinghouse motors.
2 Green Fuel Economizer Co., 108,000-c.f.m. at 8.7 in. of water, forced draft fans, driven by 900 and 600-r.p.m., 2-speed Westinghouse motors.
2 Prat-Daniel Corp., stationary plate type air preheaters, 2 sections of 104 air passages, or a total surface 36,720 sq. ft. per boiler. Outlet air temperature at normal maximum load, 480 deg. F.
2 Meehan Boiler & Construction Co., self-supporting steel stacks.

### Coal and Ash Handling Equipment

2 Fuller Lehigh Co., 10-t. per hr. Lehigh air separation type mills, geared to 720 and 515-r.p.m. Westinghouse motors. Each mill has one 15,000-c.f.m. at 12 in. of water exhauster and two drag chain conveyor feeders.
8 Fuller Lehigh Co. Calumet burners, 4 burners per boiler.
4 Richardson Scale Co., 12-t. per hr. automatic weighing and recording scales.
4 Dings Magnetic Separator Co. magnetic separators.
1 Allen-Sherman-Hoff Co. ash sluice.
8 Allen-Sherman-Hoff ash gates.
2 Morris Machine Works, 6-in., 1000-g.p.m., manganese steel centrifugal dredge pumps.

### Boiler Feed System

1 Elliott Co., 15-stage, 1700-sq. ft. heater.
1 Elliott Co., 400-sq. ft. gland steam condenser.
1 Elliott Co. open-heater, double-chamber type deaerator.
2 Youngstown Boiler & Tank Co., 20,000-gal. storage tanks.
1 Bethlehem Shipbuilding Corp., 300-sq. ft. submerged coil, Weir type, single-effect evaporator, capacity, 12,000 lb. per hr.
1 Elliott Co., 11-stage, 1700-sq. ft. heater.
1 Elliott Co., 1500-sq. ft. auxiliary turbine low-pressure heater.
1 Elliott Co., 2000-sq. ft. auxiliary turbine high-pressure heater.
1 2-in., 105-g.p.m., centrifugal, 15-stage drip pump (not yet purchased).
2 Ingersoll-Rand Co., 6-in., 1000-g.p.m., 3-stage, centrifugal tank pumps.
2 Ingersoll-Rand Co., 6-in., 3-stage, 1150-g.p.m., centrifugal boiler feed pumps, discharge pressure of 480 lb., driven by 300-hp., 1800 to 1400-r.p.m. Westinghouse motors.

### Turbines and Auxiliaries

1 General Electric Co., 33,000-kw., 17-stage, 1800-r.p.m. turbine, driving a 3-phase, 60-cycle, 11,500-v., 37,500-kv.a. generator and 175-kw., 250-v., direct connected exciter. Steam conditions at throttle, 250 lb. absolute, 217 deg. F. superheat. Turbine arranged for bleeding at stages 7, 11 and 15. Closed system generator cooling, capacity, 85,000 c.f.m.
1 General Electric Co., 2000-kw., 3600-r.p.m., 3-phase, 60-cycle, 2300-v., auxiliary turbine-generator, arranged for bleeding at 195 and 90 lb. abs., exhausting at 18 lb. abs.
1 C. H. Wheeler Mfg. Co., horizontal, 2-pass, divided water box surface condenser with surface of 50,000 sq. ft., made up of 9570 1-in., o. d., 20-ft. 2⅝-in. long Admiralty tubes furnished by Bridgeport Brass Co.
2 C. H. Wheeler Mfg. Co., 36-in., 30,000-g.p.m., centrifugal circulating pumps, driven by 300 and 257-r.p.m. Westinghouse 2-speed motors.
2 C. H. Wheeler Mfg. Co., 6-in., 750-g.p.m., 2-stage, centrifugal hotwell pumps, driven by 40-hp., 1200-r.p.m. Westinghouse motors.
4 C. H. Wheeler Mfg. Co., 2-stage Radojets; total capacity per condenser, 92 c.f.m.

### Miscellaneous Equipment

2 Chain Belt Co. Rex vertical traveling screens, 7 ft. wide, 62 ft. high.
2 Manistee Iron Works, 100-g.p.m., 6-in., single-stage, centrifugal raw water pumps.
1 Manistee Iron Works, 8-in., 1800-g.p.m., single-stage, centrifugal service water pump.
Recording pressure gages..Foxboro Co.
Draft gages.....Bailey Meter Co.
Recording thermometers.....Leeds & Northrup Co.
Steam flow meters.....Republic Flow Meter Co.
Condensate meters.....Simplex Valve & Meter Co.
$CO_2$ recorders...Permutit Co., Ranarex

signed to carry the major auxiliary load of one main unit.

While bleeding, the auxiliary unit is pressure governed and its output depends on the amount of water being fed to the boilers, just enough steam being supplied to heat the feedwater. Additional power required will automatically pick up the entire major auxiliary load. This is accomplished by automatically opening an exhaust valve on one of the bleeder lines of the turbine. Simultaneously the pressure governor is cut out of service and the bleeder valves are closed, thus permitting the machine to revert to speed governing.

Auxiliary generators provide protection for the major auxiliary service in case of station outage and, being pressure governed, they maintain a constant feedwater temperature at all loads at an efficiency which at least approaches that obtained from the same stages of the main unit. On several occasions the auxiliary turbines have been called upon to pick up the major load and have kept the station operating in spite of line troubles.

Main generator leads are carried across the boiler room direct to the transformers in the outdoor substation, with only synchronizing switches between. The room is arranged to permit extension to the ultimate station capacity of 264,000 kw. The house generators are controlled from a similar unit arranged with signal lights to indicate the failure of any of the major auxiliaries. Temperature indicators are installed on both exciter and rotor of the main units, permitting operation on a temperature basis rather than rated load. The results already obtained show that, with the generator air-cooled, more than 33,000 kw. can be carried safely. A load of 35,000 kw. has been carried continuously for 8 hr. and, with colder water in the winter, this figure will probably be exceeded.

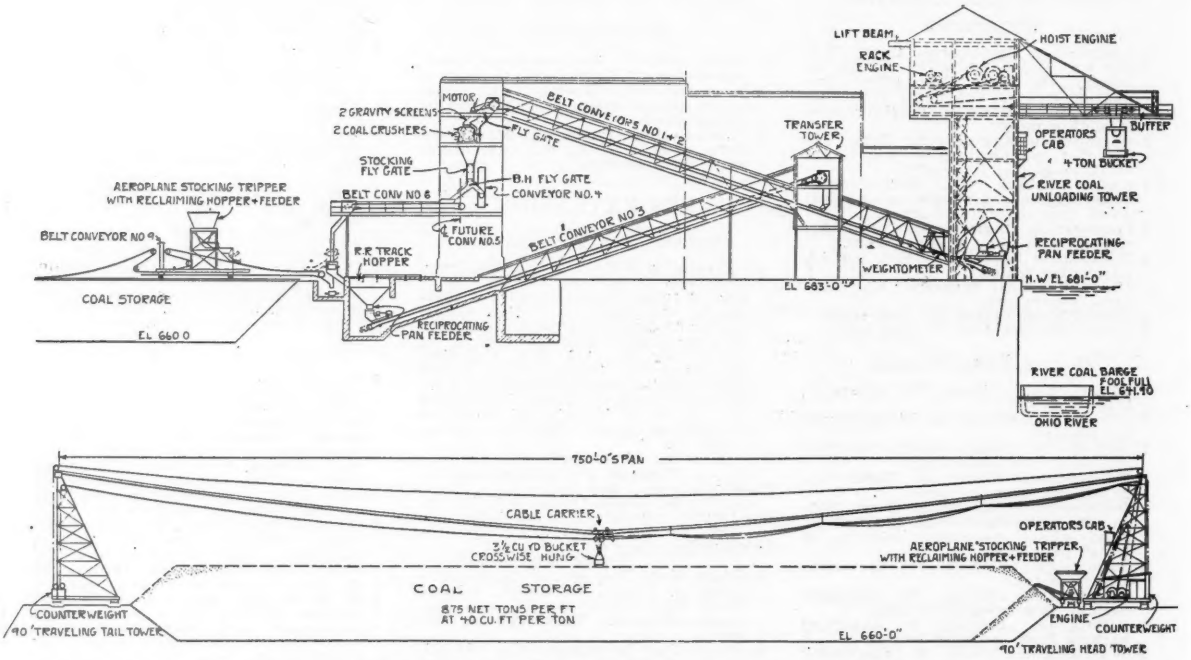



FIG. 7. DETAILS OF THE COAL HANDLING AND STORAGE EQUIPMENT

main units are paralleled only on the high side. Auxiliary service is taken off just outside each synchronizing switch with interlocking switches to prevent drawing from both machines at the same time. All the auxiliaries except the turbine driven boiler feed pump and the coal feeders on four boilers are motor driven. The motors are all designed for across-the-line starting, will carry full load with 10 per cent variation and will stand momentary variations of 30 per cent in voltage. All the auxiliary motors of 30 hp. and larger are operated at 2300 v., and the remaining equipment on 440 v. The induced draft fan motors are furnished with forced ventilation, supplied with air drawn from outside the buildings, through air filters by 20,000 and 30,000 c.f.m. fans.

Operation of the main generator is controlled through voltage regulators to vary the voltage from 10,500 v. to 12,500 v. and maintain a constant voltage at the end of the transmission line regardless of the load. Main station controls, mounted on steel panels laid out in units serving the main generators and transmission lines, are centered in the control room on the upper floor on the north end of the electrical bay. This

ROCKTON ELECTRIC CO., a subsidiary of the Wisconsin Power and Light Co., has acquired water power property on Rock River at Rockton, Ill., from the American Tar Products Co. and has announced plans for a $250,000 hydro electric plant at that point. The dam will be raised two feet to provide additional head of water to operate the plant, A. P. Gale, manager, has announced. Principal power line will be a 132,000-v. line between Beloit and Janesville and between Beloit and Belvidere, connecting in Belvidere with the Waukegan line, supplied by a steam-generating plant.

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CONSUMERS' STOCKS of bituminous coal on April 1, 1928, amounted to 48,300,000 t., according to a survey just completed by the United States Bureau of Mines, Department of Commerce. In comparison with the amount reported on January 1, 1928, the date of the last previous survey, this is a decrease of 7,200,000 t. On April 1, 1927, the stocks of bituminous coal were 75,000,000 t. In addition to stocks in the hands of consumers, there were 4,321,000 t. of bituminous coal on the docks of Lake Superior and Michigan.

# Steam and Water Power in the Electrical Industry

*By Arthur H. Markwart*

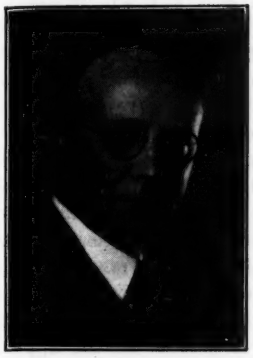

Photo by Blank-Stoller, Inc.

ARTHUR H. MARKWART graduated from the College of Civil Engineering of the University of California in 1904. He was engaged in private practice in engineering and construction management until 1920; during this period, he had charge of construction of the Panama-Pacific Exposition, filling positions of Chief of Construction and Assistant Director of Works. He entered the electrical utility business in 1920 by associating himself with the Pacific Gas and Electric Co. of San Francisco. At the present time he is vice president of that company in charge of engineering. He is a member of the American Society of Civil Engineers.

UNUSUAL INTEREST in the interrelations of fuel and water power as generating agents has arisen of late, largely in response to certain well defined tendencies of primary importance in both the construction and the operating fields of the electric power industry. Two outstanding trends present themselves. First: hydro-electric equipment has about reached the limit of its efficiency and the capital costs of such projects as remain to be constructed have an upward tendency. Second: steam plants, despite the phenomenal advance of the past decade, have not reached the limit of fuel economy. Their capital costs have a downward trend by reason of the increasing size of generating units and the increase in station capacities.

Notwithstanding these conditions, the utilization of our water powers is sound in the broadest sense, so long as it is possible at costs as low or lower than those of steam generation. While water power must compete with steam power and while economic principles must govern in this, as in all other industries, everything should be done to give it as favorable an economic position as possible. Admittedly, it is important in the interests of posterity to continue to make practical use of our water powers until they are completely developed, rather than to permit too great a demand upon our exhaustible fuel assets.

In this connection, we should also bear in mind that hydro-electric works are long-lived and relatively permanent improvements and that the cost of power from such improvements is occasioned largely by the payment of the wages of capital. Contrasted with this, steam plants are short-lived and relatively less permanent improvements, with the cost of power therefrom largely the result of paying fuel bills.

Steam-electric power may enter into the generation problem of hydro power systems in four ways: for system economy, for the short-water season of normal years, for supplementary power in dry years and, finally, for standby protection. These aspects will be discussed in order in the following paragraphs.

### STEAM FOR SYSTEM ECONOMY

When, as in the usual case, a system load factor is less than unity and when the capital cost of steam plants at load centers with relatively short transmission is less than the capital cost of hydro plant with long transmissions, it will be economical to carry a portion of the system peak with steam.

In the majority of cases, the capital costs of water power projects are high, owing in part to the necessity of expensive impounding and regulating works and the costly transmission lines required for the transportation of the power to distant load centers. While it is popularly considered that the water costs nothing, the fixed charges on the invested capital are at times so high as to remove the project from the field of economic development.

On the other hand, the capital investment per kilowatt of installed capacity in steam plants is relatively lower. This, however, is offset by the cost of fuel consumed in operation.

In general, the cost of energy from steam plants at high load factors exceeds the cost of energy from hydro plants, because of the fuel charges, whereas the cost of energy from hydro plants at low load factors exceeds the cost of that from steam plants on account of the higher fixed charges distributed over less output. Local conditions may modify these general statements but, for the vast majority of situations, the relations are as stated.

This economic interplay between steam and hydraulic energy costs suggests the possibility of a combined source of power in which steam and hydro plants will each produce in a proportion that will result in the lowest system energy cost.

Figure 1 shows a composite daily load curve[1] of a system having an annual load factor of 65 per cent. This is more or less typical of Western regional systems serving both metropolitan and rural territory with considerable agricultural and industrial diversification. By area measurement, the kilowatt-hours required for such an average day may be obtained from such a curve.

From this curve were determined the load factors and the percentages of the total kilowatt-hours from base and from peak for various percentages of the system peak, as tabulated with Fig. 1. This curve indicates, for instance, that if 65 per cent of the annual peak from base is carried on hydro plants, 88.20 per cent of the required energy will be thus supplied at a load factor of 88.3 per cent. If the remaining 35 per cent of the annual peak is carried on steam plants, the remaining 11.80 per cent of the total energy will be furnished on a load factor of 21.9 per cent.

Figure 2 gives a similar composite daily load curve

[1]Diagrams following first appeared in "Power in California," A. H. Markwart, Journal of the Franklin Institute, August, 1927.

for a load factor of 45.0 per cent, characteristic of an exclusively metropolitan load with less diversification, the elements of which will be seen to be quite different from those of Fig. 1.

With the information obtainable from these curves, the cost per kilowatt-hour from steam plants and from hydro plants may be computed for various assumptions of costs for oil, money, operation, maintenance and depreciation and for various capital costs of steam plants and hydro plants, including transmission.

| % Peak | From Base L.F. | From Base %KWHR | From Peak L.F. | From Peak %KWHR |
|---|---|---|---|---|
| 100 | 65.0 | 100.00 | 0.0 | .0 |
| 95 | 68.5 | 99.95 | 0.7 | 0.05 |
| 90 | 72.2 | 99.77 | 1.5 | 0.23 |
| 85 | 76.2 | 99.39 | 2.7 | 0.61 |
| 80 | 80.2 | 98.41 | 5.2 | 1.59 |
| 75 | 83.8 | 96.47 | 9.2 | 3.53 |
| 70 | 86.5 | 92.96 | 15.3 | 7.04 |
| 65 | 88.3 | 88.20 | 21.9 | 11.80 |
| 60 | 90.8 | 83.63 | 26.7 | 16.37 |
| 55 | 92.8 | 78.37 | 31.3 | 21.63 |
| 50 | 94.8 | 72.82 | 35.4 | 27.18 |
| 45 | 96.8 | 66.93 | 39.1 | 33.07 |
| 40 | 98.3 | 60.46 | 42.8 | 39.54 |
| 35 | 99.5 | 53.52 | 46.6 | 46.48 |
| 31 | 100 | 47.61 | 49.4 | 52.39 |
| 30 | 100 | 46.07 | 50.2 | 53.93 |
| 25 | 100 | 38.40 | 53.5 | 61.60 |
| 20 | 100 | 30.71 | 56.4 | 69.29 |
| 15 | 100 | 23.04 | 59.0 | 76.96 |
| 10 | 100 | 15.36 | 61.2 | 84.64 |
| 5 | 100 | 7.68 | 63.2 | 92.32 |
| 0 | 100 | 0.0 | 65.0 | 100.00 |

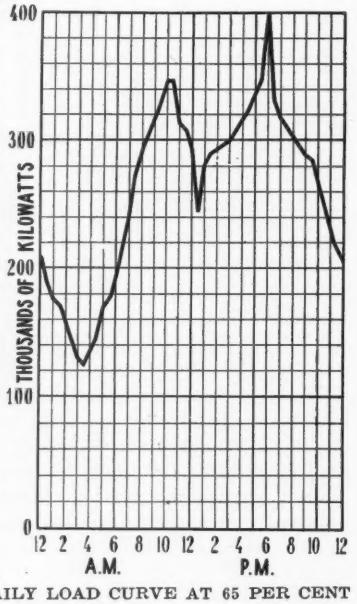


FIG. 1. COMPOSITE DAILY LOAD CURVE AT 65 PER CENT LOAD FACTOR

Cost relations resulting from these various cost assumptions for the factors entering into steam and hydro generation are shown in Fig. 3. Families of curves are shown for assumptions of hydro plant capital cost, including transmission and terminal substations, ranging from $150 to $400 per kw. of delivered peak, for the several fuel prices indicated.

Capital cost of steam plants on the 65 per cent load factor load, Fig. 3, was taken at $100 per kw., plus a capital cost for back transmission, ranging from $33 per kw. for 100 per cent steam supply, down to nothing for a 50 per cent steam supply. No allowance for back transmission capital was made for steam plants on the 45 per cent load factor load, Fig. 4, since normally such a load would be almost exclusively metropolitan.

Figures 3 and 4 indicate the total capital requirement, the annual cost, the kilowatt-hour cost and the steam and hydro load factors, respectively, for all of the chosen unit capital and fuel costs, corresponding to different percentages of the peak to be carried by steam.

Referring to Fig. 3, for instance, when the capital cost of hydro is $300 per kw. and the cost of oil is $2.00 per bbl., the cheapest combination for serving the 400,000-kw. system peak on the 65 per cent load factor is to deliver 300,000 kw. of hydro power and 100,000 kw. of steam power. To do this, a total of $100,000,000 of capital will be required. The combined annual cost will be $11,500,000 and the cost per kilowatt-hour slightly above 5 mills. The hydro plants will operate at 84 per cent load factor and the steam plants at 9 per cent. Entering Fig. 4 with the same cost assumptions, it is found that the cheapest way to serve the 45 per cent load factor load comes from 200,000 kw. of hydro power and 200,000 kw. of steam power. In this case, the required capital is $80,000,000, the annual cost is $10,300,000 and the cost per kilowatt-hour is 6.5 mills. The hydro plants will operate at 81 per cent load factor and the steam at 9 per cent.

Many other interesting deductions are possible from the diagrams. Under certain assumed conditions, for instance, considerable latitude is possible in the apportionment between steam and hydro plants without material change in the economy of production, as indicated by the flattening of the cost curves between rather wide limits of steam percentages.

Foregoing conclusions are predicted exclusively upon the economical production of kilowatt-hours, disregard-

| % Peak | From Base L.F. | From Base %KWHR | From Peak L.F. | From Peak %KWHR |
|---|---|---|---|---|
| 100 | 45.0 | 100.00 | 0.0 | .0 |
| 95 | 47.3 | 99.96 | 0.4 | 0.04 |
| 90 | 49.8 | 99.81 | 0.8 | 0.19 |
| 85 | 52.6 | 99.59 | 1.3 | 0.41 |
| 80 | 55.7 | 99.26 | 1.7 | 0.74 |
| 75 | 59.2 | 98.77 | 2.2 | 1.23 |
| 70 | 62.8 | 98.07 | 2.9 | 1.93 |
| 65 | 67.0 | 96.96 | 3.9 | 3.04 |
| 60 | 71.3 | 95.43 | 5.1 | 4.57 |
| 55 | 76.3 | 93.39 | 6.6 | 6.61 |
| 50 | 80.9 | 90.09 | 8.9 | 9.91 |
| 45 | 83.7 | 83.70 | 13.3 | 16.30 |
| 40 | 86.0 | 76.61 | 17.5 | 23.39 |
| 35 | 88.7 | 69.12 | 21.3 | 30.88 |
| 30 | 91.7 | 61.21 | 24.9 | 39.79 |
| 25 | 94.7 | 52.75 | 28.3 | 47.25 |
| 20 | 98.2 | 43.73 | 31.6 | 56.27 |
| 15 | 100. | 33.41 | 35.2 | 66.59 |
| 10 | 100. | 22.27 | 38.8 | 77.73 |
| 5 | 100. | 11.15 | 42.0 | 88.86 |
| 0 | 100. | 0.0 | 45.0 | 100.00 |

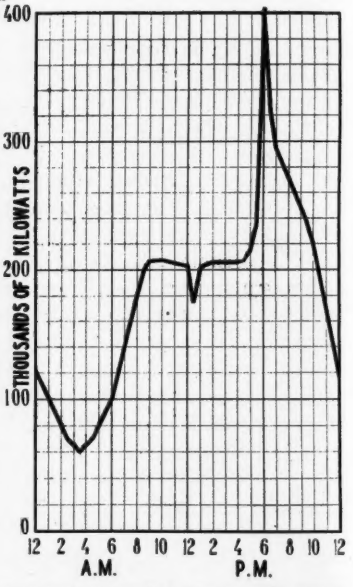


FIG. 2. COMPOSITE DAILY LOAD CURVE AT 45 PER CENT LOAD FACTOR

ing all other considerations. These statements have as their basis primary hydro power for the bottom of the load and neglect consideration of annual low water seasons and years of deficient water supply. They also neglect consideration of the energy which might be generated by steam plants running regularly as standbys on reduced loads.

### Steam for Short Water Season

Even when hydro plants are put on a favorable load factor by combing off an economic portion of the system peak with steam, ideal conditions for the hydro plants do not necessarily exist. Conditions would be ideal if the stream discharge curve were identical in shape with the hydro load curve that remains after the steam has supplied its economic portion of the whole. Daily fluctuation of load may be disregarded since that, as a rule,

is cared for by forebay capacity. Monthly fluctuations are not so easily met, because storage sites adequate to equalize fully the natural flows of the streams are seldom found. It then becomes necessary during the short-water season of three to six months, depending upon the character of the watershed and the precipitation to supply the difference between the available hydro power and the desired hydro power by additional steam-generated energy. It behooves the hydro power companies, therefore, to make every effort to effect all possible storage reserves, when economically possible, against the seasonal short-water period, as such provisions mean a substantial fuel saving, particularly when fuel costs are high.

While the foregoing comments relate principally to primary hydro power, available for the larger portion of the time, a similar discussion may be made respecting the greater use of steam in absorbing secondary hydro power such as is increasingly available in the West in the form of by-product power from storage works erected primarily for irrigation. Almost 60 per cent of the annual irrigation demand is required during the three summer months. Accordingly, such by-product hydro plants must be increased in capacity to absorb this flow, as regulated solely to answer irrigation demands. Under such a condition, the seasonal makeup from steam would be much greater than if the stored water were discharged at a rate suitable to meet power needs rather than those of irrigation.

### Steam for Dry Years

Dry-year steam, as distinguished from short-water steam, is that required to make up the deficiency of hydro power which exists in years when the precipitation and runoff are below normal. The amount of dry-year steam will depend, among other things, upon the degree to which the streams have been utilized. A stream developed for an average flow that is sustained over many years of a period of record will require less steam-electric power to meet deficiencies in hydro energy on dry years than would be required for a stream developed for a higher average flow that is sustained only over the fewer years of the period that had the higher water yields; again, less steam-electric power than a stream which had been developed only for the average flow that is sustained over a few years of the period that has the lower water yields.

What actually takes place in dry years, as contrasted with normal water years, is that the steam power takes its position on the base of the load immediately above the hydro load that is being carried on stream-flow plants not subject to daily regulation. The portion of the load lying above this base steam power will be carried, so far as possible, by such hydro plants as have forebay regulation; the final balance will be carried by steam, if the steam plants are not carrying their full capacity on the base load.

Thus, if power consumption is not to be curtailed in dry years, steam plant capacity must be provided to meet dry-year hydro power deficiency when it occurs. This is essential even though, for some reason or other, steam standby protection at load centers is deemed superfluous and the economic combing off of the peak with steam is unnecessary.

Entirely apart from considerations of steam for dry years and for short water seasons, other factors arise to affect the extent of steam standby for a regional hydro power supply. The proper amount of standby capacity is determined by the amount of preferred service required at metropolitan centers, by the character of the load carried, by the kind of general service desired to be given and by other policy considerations.

As an exceedingly conservative provision, standby to the extent of 100 per cent of the expected metropolitan peak would be the maximum. It is probable that 75 per cent protection would be adequate in most instances, for as a rule there is more than one source of power into such load centers.

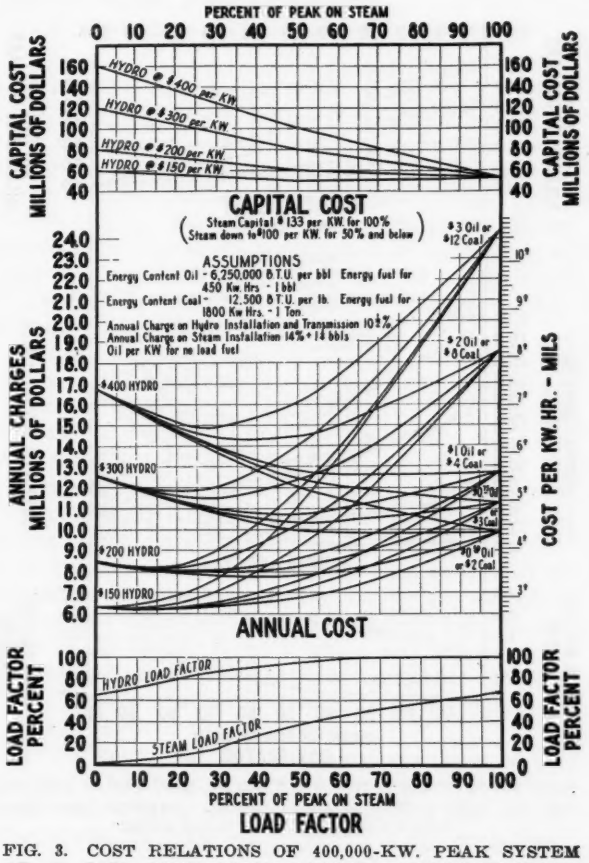
PERCENT OF PEAK ON STEAM
0 10 20 30 40 50 60 70 80 90 100
CAPITAL COST MILLIONS OF DOLLARS
HYDRO @ $400 per KW.
HYDRO @ $300 per KW.
HYDRO @ $200 per KW.
HYDRO @ $150 per KW.
CAPITAL COST
(Steam Capital $133 per KW. for 100% Steam down to $100 per KW. for 50% and below)
ASSUMPTIONS
Energy Content Oil - 6,250,000 B.T.U. per bbl Energy fuel for 450 Kw. Hrs. - 1 bbl
Energy Content Coal - 12,500 B.T.U. per lb. Energy fuel for 1800 Kw. Hrs. - 1 Ton
Annual Charge on Hydro Installation and Transmission 10½%
Annual Charge on Steam Installation 14% + 14 bbls Oil per KW for no load fuel
$3 Oil or $12 Coal
$2 Oil or $8 Coal
$1 Oil or $4 Coal
$400 HYDRO
$300 HYDRO
$200 HYDRO
$150 HYDRO
ANNUAL CHARGES MILLIONS OF DOLLARS
COST PER KW. HR. - MILS
ANNUAL COST
HYDRO LOAD FACTOR
STEAM LOAD FACTOR
LOAD FACTOR PERCENT
PERCENT OF PEAK ON STEAM
LOAD FACTOR

FIG. 3. COST RELATIONS OF 400,000-KW. PEAK SYSTEM AT 65 PER CENT LOAD FACTOR. HYDRO-ELECTRIC POWER ASSUMED AS BASE LOAD

Installation to furnish protection to this extent would operate to reduce the total peak, permitting the hydro plants to furnish the bulk of the kilowatt-hours on the base at an improved hydro plant load factor.

Experience in northern California shows that standby steam capacity based on 75 per cent of the metropolitan peak is also sufficient as a steam reserve against dry years.

Energy production from standby plants, while standing by to take full or partial loads, will vary with the size of the units installed, the smaller units being capable of operation at smaller minimum loads than the larger units. As a large system may have several steam plants, the kilowatt-hours produced from such stations will vary with the number of standby plants

and the number of units that may be operating in the several plants.

### Application of Principles

Desired steam plant capacity in a combined system will be determined by the various considerations discussed above. Hydro plant capacity, on the other hand, is dependent solely on the question of economy in kilowatt-hour production. While the principles relating to the joint usage of steam and water power in a regional system may be demonstrated readily from the viewpoint of economic generation, their ideal application is seldom or never possible. Existing systems, which generally have been constructed by units over a period of years,

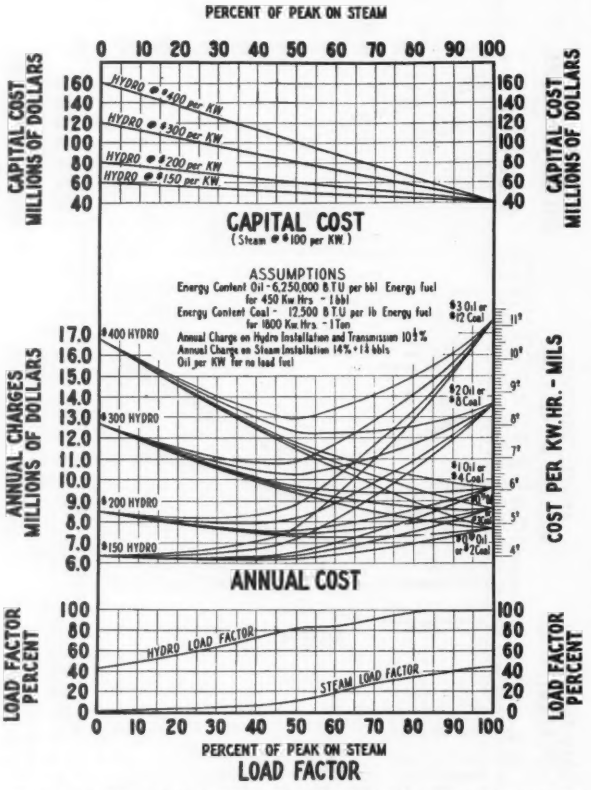
PERCENT OF PEAK ON STEAM
CAPITAL COST MILLIONS OF DOLLARS
HYDRO @ $400 per KW
HYDRO @ $300 per KW
HYDRO @ $200 per KW
HYDRO @ $150 per KW
CAPITAL COST
(Steam @ $100 per KW)
ASSUMPTIONS
Energy Content Oil - 6,250,000 BTU per bbl Energy fuel for 450 Kw Hrs. - 1 bbl
Energy Content Coal - 12,500 BTU per lb Energy fuel for 1800 Kw Hrs. - 1 Ton
Annual Charge on Hydro Installation and Transmission 10½%
Annual Charge on Steam Installation 14% + 18 bbls Oil per KW for no load fuel
ANNUAL CHARGES MILLIONS OF DOLLARS
COST PER KW.HR. - MILS
$400 HYDRO
$300 HYDRO
$200 HYDRO
$150 HYDRO
$3 Oil or $12 Coal
$2 Oil or $8 Coal
$1 Oil or $4 Coal
$0 Oil or $2 Coal
ANNUAL COST
LOAD FACTOR PERCENT
HYDRO LOAD FACTOR
STEAM LOAD FACTOR
PERCENT OF PEAK ON STEAM
LOAD FACTOR

FIG. 4. COST RELATIONS OF 400,000-KW. PEAK SYSTEM AT 45 PER CENT LOAD FACTOR. HYDRO-ELECTRIC POWER ASSUMED AS BASE LOAD

must be taken into consideration and the best practical economy obtained from them.

Where additional power is needed, therefore, the general procedure is to combine new with existing supplies to effect a maximum economy of both. Such a rule makes for the conservation of our fuel supply and for the realization of the best economic advantages at the time and under the circumstances prevailing. For example, it will often be economic, where added power is needed for a given system composed of hydro-electric plants and extended transmission network, to supply the added power from steam plants in favorable positions in major load centers to run on base load, because substantially no additional transmission investment will be required. On the other hand, for a system supplied by steam-generated power, it may be advantageous to resort to favorably situated hydro plants, to run likewise on base load, particularly if such a system will thereby increase its load factor by reason of an extension of its market beyond the metropolitan areas where steam plants are situated. Other examples might be cited, such as adding steam plants on the top to effect the improvement of the hydro plant load factor, or hydro plants on the top to reduce the steam plant capacity and to reduce fuel consumption by using stream flow. As a rule and particularly in the West, economy will be obtained for the present by the use of a reasonable portion of steam power generally to carry the top of the load, particularly on account of greater economies in fuel burning stations and because land values and water rights in power developments continue to rise in price.

### Cost of Power

"Cost of power[2] from such a regional system naturally will vary from year to year. The total of fixed and other annual charges on hydro and steam-plant capacity will remain substantially the same irrespective of the output, whereas the fuel charge will vary, depending upon the hydro power deficiency. In dry years, a portion of the hydro plant capacity will be nonproductive and in wet years this condition will obtain with respect to steam plant capacity. Because of this, the cost of power is not constant, even though unit fuel cost and fixed charges are stationary over a long period of time. Average cost of energy, however, may be ascertained with reasonable accuracy but only if a period of years which contains a dry cycle is considered. It is possible to make a summation of annual costs for such a period and to apply these to the total of kilowatt-hours expected from hydro and steam plants for the period, thus obtaining a period average unit cost of energy. The total cost will be made up of the fixed charges on the capital invested in hydro plants, including transmission, also in steam plants, plus operation, maintenance, depreciation and similar costs on both, plus the fuel costs over the period considered."

### Conclusion

In the final analysis, the relative development of combined hydro plant and steam plant generating capacity is a problem of economy. Natural resources available, character of the load to be carried, rate at which energy must be supplied or the load factor, extent to which other utilities may depend upon it for standby and other related elements furnish the criteria for its solution.

While there are several variables in this economic problem and while it is complex to a certain extent, it is subject to a reasonable solution. To that end, the economy and utility of combined hydro plant and steam plant generation are being studied, for it is dependable central station power at the lowest present and future cost, so far as this can be determined, that is the prime objective of utility managements.

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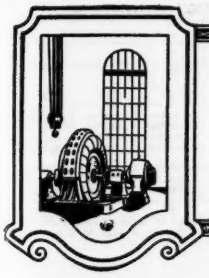
Western Society of Engineers has removed its office, auditorium and library to Suite 1200, Engineering Building, 205 Wacker Drive, Chicago. In future, all meetings will be held in the new quarters, where a reading room and a room for the convenience of members will be maintained.

[2] "Aspects of Steam Power in Relation to a Hydro Supply," A. H. Markwart. Proceedings of American Society of Mechanical Engineers, Vol. 48, 1926.



# ELECTRICAL MACHINERY FOR LIGHT AND POWER

# Voltage Drop Calculations Made Easy

TABULATED DATA ON TRANSMISSION LINE CONSTANTS PERMITS SIMPLE METHOD OF CALCULATING VOLTAGE DROP. BY FRED C. DE WEESE

FROM THE TITLE of this article the reader may get the impression that some new methods have been derived for making voltage drop calculations. Such, however, is not the case. It means only that the data has been collected here and condensed in such a form that, by its use, the calculations necessary for determining voltage drop, or load carrying capacity of a particular transmission or distribution circuit are reduced to a minimum and higher mathematics eliminated entirely.

Engineers associated with the large utilities and engineering concerns of today do not have the time to go into detail calculations every time it is necessary to figure out the voltage drop of every new extension contemplated, or for a small line already in operation.

An attempt is made here to explain the methods used by the writer for making voltage drop calculations. A few typical examples are assumed and the work carried out in detail. The demonstrations are clear and are intended to require a minimum amount of time and work in order to arrive at the answer to any particular problem when the proper information is available.

Before going into the work in detail, explanations will be given as to the method of compiling the tables and making up the curves.

The first essential is to compute the volts drop per kilowatt per mile. Preferably these calculations should be made for 100 v. It is necessary to make these calculations for all standard sizes of conductors, spacings and for various power factors, met with in standard overhead practice. It is necessary only to compile the tables for 80 per cent power factor, curves being plotted to show the ratio of load or voltage drop of other power factors to that at 80 per cent. By the use of these curves we have the advantage that intermediate power factors may be read. These curves must be plotted for different spacings of the various sizes of conductors, as there is a wide difference in the load or voltage drop at the different spacings; especially is this true for the larger size conductors.

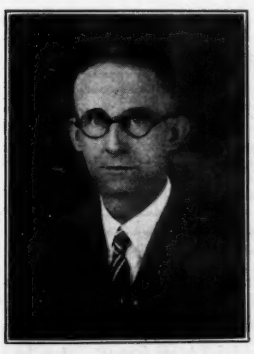
When the word "spacing" is used, it should be understood to mean "equivalent spacing". The calculations are made for power factors from 50 to 95 per cent, inclusive, in steps of 5 per cent. Also, they are made for 96, 97, 98, 99 and 100 per cent.

Tables are also made up for use in determining the ratio of load, or voltage drop, of one size of conductor to that of any other size.

A distance correction curve is plotted, to be used to correct for charging current, for lines of any considerable length. This curve was plotted from values computed by the Dwight formula, which is as follows:

$100K\ (L/1000)^2$ = per cent correction for line charging current, where K equals 2.16 for 60 cycles and L equals length of line in miles.

It is a known fact that the charging current of the line has a tendency to increase the voltage from the supply end towards the receiving end of a line; or, in other words, the drop will be less for a line containing



Fred C. De Weese is Assistant Engineer with the Carolina Power and Light Co. with headquarters at Raleigh, N. C. Mr. De Weese has had extensive practical experience in various branches of electrical work and for a number of years has been a frequent contributor to Power Plant Engineering and other technical publications. From 1918, his engineering experience has been as follows: From 1918-20, chief engineer of the General Explosives Co., Joplin, Mo.; 1920-21, in charge of a plant of the Western Utilities Co., Edgemont, S. Dakota; 1921-24, general superintendent, Eastern Minnesota Power Co., with headquarters at Pine City, Minn. There he was in charge of all engineering, design and construction of all transmission lines, substations and distribution systems. In April, 1924, he was engaged to do special engineering work on distribution with the Louisville Gas and Electric Co., and in 1926 he entered upon the position with the Carolina Power and Light Co. which he occupies at present.

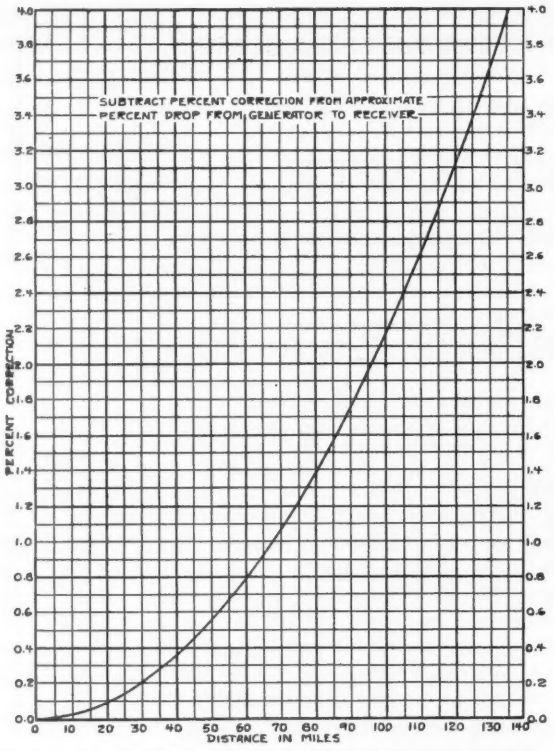

SUBTRACT PERCENT CORRECTION FROM APPROXIMATE PERCENT DROP FROM GENERATOR TO RECEIVER.
PERCENT CORRECTION
DISTANCE IN MILES
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0

FIG. 1. DISTANCE CORRECTION CURVE TO CORRECT FOR CHARGING CURVE. BASED ON THE DWIGHT FORMULA $100\ K\ (L \div 1000)^2 =$ PER CENT CORRECTION

charging current, for the same load, than if there were no charging current present. This is negligible for very short lines; however, for lines of a greater length than 20 mi., the correction should be made, if accurate results are desired.

### Use of the Tables and Curves

In order to demonstrate the use of the tables and curves, as used for voltage drop calculations, a few typical examples will be chosen and the work carried through.

What will be the voltage drop in per cent of the receiving end voltage, 60 kv., 65 mi., 5000 kv.a., 4000 kw., 80 per cent p. f., 4/0 copper, spacing 7 ft.?

From Table I, for 4/0 copper, 7 ft., we read 0.002344.

$$\frac{65 \times 4000 \times 0.002344}{100} = 6.0944 \text{ per cent}$$

From Fig. 1, the correction for 65 miles is 0.91. 6.0944 — 0.91 = 5.1844 per cent, which is the net voltage drop.

In making calculations, such as above, always remember to move the decimal point two places to the left, in order to have the answer read directly in per cent, then it will not be necessary to write the denominator in the equation.

Suppose it is desired to know how much load the above line will carry, on condition that a synchronous condenser is to be installed, of sufficient capacity to raise the power factor to 98 per cent.

From Fig. 3, 4/0 wire, 98 per cent power factor, we read 1.91. Then, 1.91 × 4000 = 7640 kw. Or, if we

TABLE I. CONDUCTOR AND SPACING CONSTANTS

| | 60,000 Volts | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Spacing in Feet | | | | | | | |
| | 3 | 4 | 5 | 7 | 9 | 11 | 13 | 15 |
| #2 Copper | 0.003925 | 0.003999 | 0.004052 | 0.004133 | 0.004206 | 0.004245 | 0.004296 | 0.004336 |
| #1 " | 0.003589 | 0.003464 | 0.003523 | 0.003615 | 0.003674 | 0.003728 | 0.003768 | 0.003809 |
| #1/0 " | 0.002964 | 0.003039 | 0.003098 | 0.003103 | 0.003252 | 0.003307 | 0.003350 | 0.003388 |
| #2/0 " | 0.002622 | 0.002698 | 0.002757 | 0.002847 | 0.002912 | 0.002968 | 0.003012 | 0.003049 |
| 3/0 " | 0.002346 | 0.002423 | 0.002482 | 0.002573 | 0.002636 | 0.002694 | 0.002734 | 0.002776 |
| 4/0 " | 0.002124 | 0.002198 | 0.002258 | 0.002344 | 0.002414 | 0.002471 | 0.002511 | 0.002550 |
| 250,000 CM | 0.001944 | 0.002048 | 0.002107 | 0.002196 | 0.002265 | 0.002325 | 0.002365 | 0.002404 |

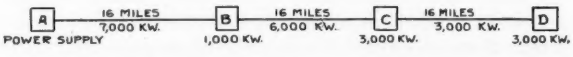
Constants are for 80% PF.
Multiply constant, for any size conductor and spacing, by Kilowatts x Miles, move the decimal point two places to the left, and the result will be the voltage drop directly in percent.

wish to know what the voltage drop will be for 4000 kw., 98 per cent power factor, 6.0944/1.91 = 3.19 per cent. The net drop, in this case, will be 3.19 — 0.91 = 2.28 per cent.

In a great many cases coming up for solution, there are two or more loads supplied from the same line and at different points along the line. Problems of this kind are usually worked out as follows:

The total kw.m. (kilowatt-miles) are determined and this value multiplied by some value as given in Table I.

The following example is self-explanatory from the sketch.




Total length of line from A to D, 51 mi. No. 1 copper, 60 kv., 7-ft. spacing.

(a) What will be the voltage drop from A to D at 80 per cent p. f.?

(b) What will be the voltage drop from A to D at 100 per cent p. f.?

(c) How much load will a 4/0 copper line carry,

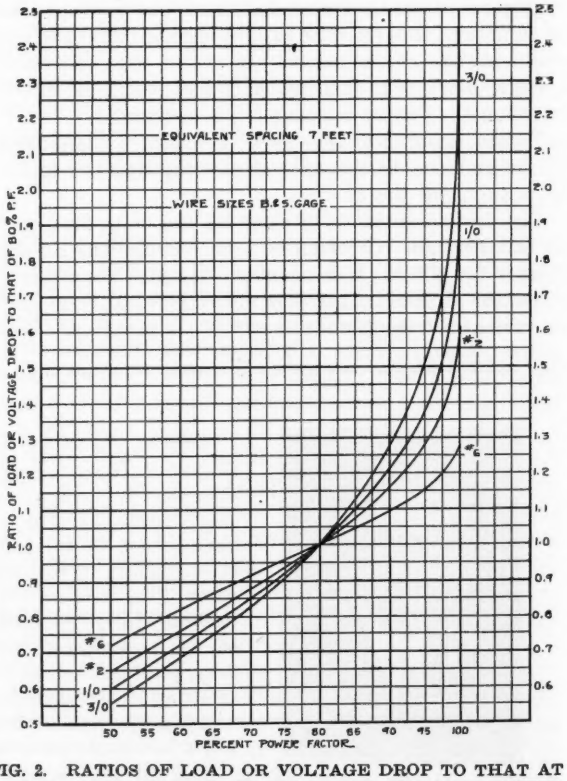

EQUIVALENT SPACING 7 FEET
WIRE SIZES B.&S. GAGE
3/0
1/0
#2
#6
RATIO OF LOAD OR VOLTAGE DROP TO THAT OF 80% P.F.
PERCENT POWER FACTOR
50 55 60 65 70 75 80 85 90 95 100
0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0 2.1 2.2 2.3 2.4 2.5

FIG. 2. RATIOS OF LOAD OR VOLTAGE DROP TO THAT AT 80 PER CENT POWER FACTOR, FOR VARIOUS POWER FACTORS

with the same voltage drop as for No. 1, at 80 per cent p. f.?

$$16 \times 3000 = 48{,}000 \text{ kw.m. C to D}$$
$$16 \times 6000 = 96{,}000 \text{ kw.m. B to C}$$
$$19 \times 7000 = 133{,}000 \text{ kw.m. A to B}$$

Total kw.m. 277,000

Since the value for No. 1 copper at 7-ft. spacing, given in Table I, is 0.003615, the per cent drop is

$$277{,}000 \times 0.003615 = 10.01355 \text{ per cent}$$

Correction for 51 mi., from Fig. 1, is 0.565.

$10.01355 - 0.565 = 9.449$ per cent, as the net drop

Unless the line is quite long and heavily loaded, with loads at several different points, the above method will be sufficiently accurate for all practical purposes; however, we will make the calculations by a method that takes into account the voltage delivered at each station and see what the error is for this particular case.

Volts drop per kw. per mile, at 100 v., 80 per cent power factor, 7-ft. spacing, No. 1 copper, is 3600* $\times$ 0.003615 = 13 v. Ratio of drop at 100 v. to that at 60,000 v. equals 60,000/100 = 600.

$$\frac{13 \times 16 \times 3000}{600} = 1040 \text{ v., C to D}$$

The voltage delivered at C will be 60,000 + 1040 = 61,040 v. Pointing off two places we have 610.4.

$$\frac{13 \times 16 \times 6000}{610.4} = 2028 \text{ v. drop, B to C}$$

$$61.040 + 2028 = 63{,}068 \text{ v. at B.}$$

$$\frac{13 \times 19 \times 7000}{630.68} = 2740 \text{ v. drop, A to B}$$

$$1040 + 2028 + 2740 = 5808 \text{ v. drop from A to D}$$

$$5808/60{,}000 \times 100 = 9.68 \text{ per cent}$$

$$9.68 - 0.565 = 9.115 \text{ per cent net drop}$$

Error by the first method equals 10.0135 — 9.68 = 0.3335 per cent. For a line 51 mi. long, supplying loads at three different places, an error of one-third of one per cent is certainly not out of the way. Another thing to be kept in mind is that the drop, as computed by the first method will always be on the safe side. The operations for determining the answer, by the last method, are 2.33 times as many as by the first.

Solution for (b):

By referring to the power factor load ratio curve, for No. 1 copper, 100 per cent power factor, 7-ft.

TABLE II. RATIO OF LOADS OF DIFFERENT SIZE CONDUCTORS. EQUIVALENT SPACING 5 FT.

| | #6 | #4 | #2 | #1 | 1/0 | 2/0 | 3/0 | 4/0 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| #6 | 1.000 | 1.435 | 1.968 | 2.296 | 2.570 | 2.900 | 3.216 | 3.530 | 3.785 | 4.021 | 4.242 | 4.417 | 4.545 | 4.675 |
| #4 | 0.697 | 1.000 | 1.372 | 1.580 | 1.797 | 2.022 | 2.240 | 2.460 | 2.637 | 2.804 | 2.956 | 3.080 | 3.167 | 3.260 |
| #2 | 0.508 | 0.728 | 1.000 | 1.152 | 1.311 | 1.473 | 1.632 | 1.792 | 1.922 | 2.044 | 2.155 | 2.245 | 2.308 | 2.375 |
| #1 | 0.441 | 0.633 | 0.868 | 1.000 | 1.137 | 1.279 | 1.418 | 1.557 | 1.669 | 1.774 | 1.870 | 1.948 | 2.004 | 2.063 |
| 1/0 | 0.387 | 0.556 | 0.763 | 0.879 | 1.000 | 1.124 | 1.247 | 1.368 | 1.468 | 1.560 | 1.645 | 1.713 | 1.760 | 1.813 |
| 2/0 | 0.345 | 0.494 | 0.678 | 0.782 | 0.889 | 1.000 | 1.108 | 1.217 | 1.305 | 1.387 | 1.462 | 1.523 | 1.567 | 1.612 |
| 3/0 | 0.311 | 0.446 | 0.613 | 0.705 | 0.803 | 0.905 | 1.000 | 1.098 | 1.178 | 1.252 | 1.320 | 1.375 | 1.413 | 1.455 |
| 4/0 | 0.283 | 0.406 | 0.558 | 0.642 | 0.731 | 0.822 | 0.911 | 1.000 | 1.072 | 1.140 | 1.202 | 1.252 | 1.288 | 1.326 |
| 250 | 0.264 | 0.379 | 0.520 | 0.599 | 0.682 | 0.766 | 0.849 | 0.933 | 1.000 | 1.063 | 1.122 | 1.168 | 1.200 | 1.236 |
| 300 | 0.249 | 0.356 | 0.489 | 0.563 | 0.641 | 0.721 | 0.799 | 0.877 | 0.941 | 1.000 | 1.055 | 1.098 | 1.130 | 1.163 |
| 350 | 0.236 | 0.338 | 0.464 | 0.535 | 0.608 | 0.684 | 0.758 | 0.832 | 0.892 | 0.948 | 1.000 | 1.042 | 1.071 | 1.102 |
| 400 | 0.226 | 0.325 | 0.445 | 0.513 | 0.584 | 0.656 | 0.727 | 0.799 | 0.856 | 0.911 | 0.960 | 1.000 | 1.028 | 1.058 |
| 450 | 0.220 | 0.316 | 0.433 | 0.499 | 0.567 | 0.638 | 0.707 | 0.777 | 0.833 | 0.885 | 0.934 | 0.973 | 1.000 | 1.030 |
| 500 | 0.214 | 0.307 | 0.421 | 0.485 | 0.551 | 0.621 | 0.687 | 0.755 | 0.810 | 0.860 | 0.907 | 0.945 | 0.971 | 1.000 |

*60 kv.2

TABLE III. RATIO OF LOADS OF DIFFERENT SIZE CONDUCTORS. EQUIVALENT SPACING 7 FT.

| | SIZE OF CONDUCTOR | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | #6 | #4 | #2 | #1 | 1/0 | 2/0 | 3/0 | 4/0 | 250 | 300 | 350 | 400 | 450 | 500 |
| #6 | 1.000 | 1.423 | 1.943 | 2.235 | 2.536 | 2.830 | 3.135 | 3.438 | 3.695 | 3.925 | 4.078 | 4.340 | 4.365 | 4.500 |
| #4 | 0.703 | 1.000 | 1.365 | 1.570 | 1.778 | 1.983 | 2.195 | 2.410 | 2.585 | 2.730 | 2.860 | 2.972 | 3.060 | 3.156 |
| #2 | 0.514 | 0.732 | 1.000 | 1.145 | 1.298 | 1.453 | 1.606 | 1.762 | 1.877 | 2.000 | 2.093 | 2.175 | 2.240 | 2.310 |
| #1 | 0.448 | 0.635 | 0.870 | 1.000 | 1.132 | 1.265 | 1.400 | 1.536 | 1.633 | 1.740 | 1.822 | 1.895 | 1.950 | 2.005 |
| 1/0 | 0.394 | 0.562 | 0.769 | 0.880 | 1.000 | 1.117 | 1.236 | 1.356 | 1.449 | 1.536 | 1.610 | 1.673 | 1.724 | 1.776 |
| 2/0 | 0.354 | 0.504 | 0.688 | 0.790 | 0.894 | 1.000 | 1.105 | 1.213 | 1.290 | 1.375 | 1.438 | 1.495 | 1.540 | 1.588 |
| 3/0 | 0.320 | 0.456 | 0.622 | 0.715 | 0.808 | 0.904 | 1.000 | 1.096 | 1.169 | 1.243 | 1.300 | 1.366 | 1.392 | 1.435 |
| 4/0 | 0.292 | 0.415 | 0.566 | 0.651 | 0.736 | 0.825 | 0.911 | 1.000 | 1.067 | 1.132 | 1.185 | 1.232 | 1.268 | 1.310 |
| 250 | 0.273 | 0.389 | 0.527 | 0.610 | 0.690 | 0.772 | 0.854 | 0.937 | 1.000 | 1.062 | 1.111 | 1.156 | 1.190 | 1.226 |
| 300 | 0.258 | 0.366 | 0.500 | 0.575 | 0.650 | 0.727 | 0.805 | 0.883 | 0.942 | 1.000 | 1.046 | 1.089 | 1.120 | 1.155 |
| 350 | 0.246 | 0.350 | 0.478 | 0.549 | 0.621 | 0.695 | 0.769 | 0.844 | 0.900 | 0.956 | 1.000 | 1.040 | 1.070 | 1.104 |
| 400 | 0.237 | 0.337 | 0.460 | 0.528 | 0.598 | 0.668 | 0.740 | 0.812 | 0.866 | 0.920 | 0.962 | 1.000 | 1.030 | 1.062 |
| 450 | 0.230 | 0.327 | 0.446 | 0.513 | 0.580 | 0.648 | 0.718 | 0.788 | 0.840 | 0.893 | 0.934 | 0.970 | 1.000 | 1.030 |
| 500 | 0.223 | 0.317 | 0.433 | 0.497 | 0.563 | 0.629 | 0.696 | 0.764 | 0.815 | 0.866 | 0.906 | 0.942 | 0.970 | 1.000 |

spacing, we find the value, on the right-hand side of the sheet, to be 1.735. Dividing the drop at 80 per cent power factor, we have

$$\frac{10.0135}{1.735} = 5.75 \text{ per cent.} \quad 5.75 - 0.565 = 5.185$$

net voltage drop. This is the drop for the same loads and same conductor size, when the load is transmitted at 100 per cent power factor instead of at 80 per cent.

Solution for (c):

Using Table III and reading down from 4/0 conductor to 1.000 and across to the left to the column under No. 1, we find a value 0.651. Dividing the loads at B, C and D by 0.651, we find that they will be 1537, 4608 and 4608, respectively. These are the loads that

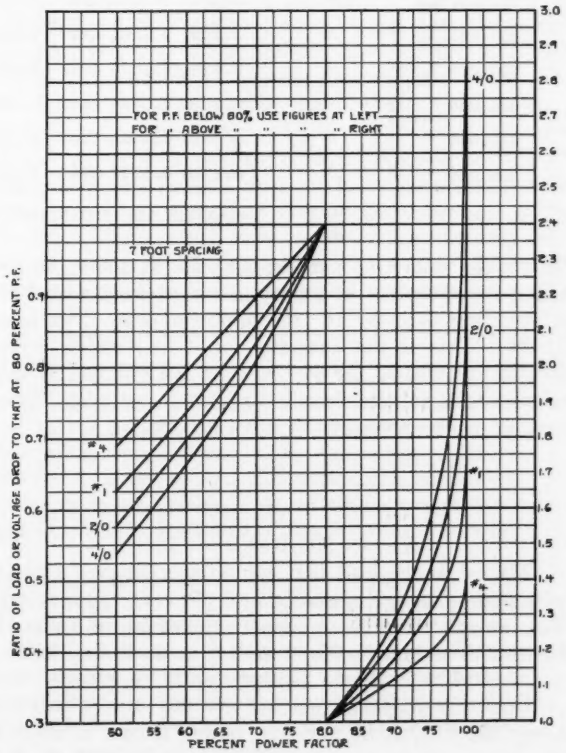

FOR P.F. BELOW 80% USE FIGURES AT LEFT
FOR " ABOVE " " " " RIGHT
7 FOOT SPACING
4/0
2/0
#1
#4
RATIO OF LOAD OR VOLTAGE DROP TO THAT AT 80 PERCENT P.F.
PERCENT POWER FACTOR
50 55 60 65 70 75 80 85 90 95 100
0.3 0.4 0.5 0.6 0.7 0.8 0.9
1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0 2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 2.9 3.0

FIG. 3. RATIOS OF LOAD OR VOLTAGE DROP TO THAT AT 80 PER CENT POWER FACTOR, FOR VARIOUS POWER FACTORS

can be carried over 4/0 conductor, with the same voltage drop as 1000, 3000 and 3000 kw., respectively, at B, C and D.

Suppose the problem is one for the distribution engineer. For instance, it is desired to know the amount of load that can be transmitted over a No. 4 copper conductor, three-quarters of a mile, 4000 v., three-phase, 80 per cent power factor, 5-ft. spacing, at 5 per cent voltage drop.

By referring to Table I, it will be seen that No. 2 copper is the smallest size for which any values are shown. (No. 2 is the smallest size copper that should be used at 60 kv., on account of corona.) This need not disturb the situation, however, for we shall be able to solve the problem any way. The value for No. 2, 5-ft. spacing, is 0.004053. Multiplying this value by 3600 (the square of 60 kv.), we have a product of 14.59. This is the volts drop per kw. per mile, at 100 v., 80 per cent power factor. As we are now concerned with 4000 v., dividing 14.59 by 16 (the square of 4 kv.), we have 0.9119. This is the constant for 4 kv., which corresponds to 0.004053 for 60 kv. For the purpose of this solution, the voltage drop is fixed at 5 per cent; therefore, it will be necessary to solve for kw.

$$\frac{0.9119 \times 0.75 \times \text{Kw.}}{100} = 5 \text{ per cent}$$

$$\text{Kw.} = 500/0.6839 = 731.$$

731 kw. is the load that can be carried over a No. 2 wire *three-quarters of a mile*, at 5 per cent voltage drop. But, we are using No. 4 copper; therefore, in Table II, horizontal column for No. 2 under No. 4, we find 0.728.

$$0.728 \times 731 = 532 \text{ kw. for No. 4 wire}$$

Upon investigation, we find that No. 4 wire will not carry 532 kw., at 80 per cent power factor, as short a distance as three-quarters of a mile, with a drop of 5 per cent, without exceeding the allowable current-carrying capacity of the conductor; therefore, it will be necessary to reduce the load to approximately 500 kw. When the load is reduced, the voltage drop will be reduced in a like proportion.

$$500/532 \times 100 = 4.7 \text{ per cent drop}$$

The answer to the foregoing problem is 500 kw., for which the voltage drop will be 4.7 per cent.

While the tables and curves are made up for 80 per cent power factor, they may also be used for other conditions. For example, suppose that in the first problem the 4000-kw. load was transmitted at 85 per cent power factor, instead of at 80 per cent. From Fig. 3, the value for 85 per cent power factor, 4/0 copper, is seen to be 1.131 and for 98 per cent 1.91. Then the load at 98 per cent power factor will be

$$\frac{4000}{1.131} \times 1.91 = 6750 \text{ kw.}$$

That is, 6750 kw. will be the load at 98 per cent power factor, to have the same voltage drop as 4000 kw. at 85 per cent. Other conditions of power factor are handled in the same way.

From the preceding, it may readily be seen that by a little juggling of figures, when data, such as herein contained, is available, almost any kind of a problem or combination of problems may be solved, with a small amount of work. The flexibility of these data is more readily apparent when it is considered that it was originally intended to cover a 60-kv. problem.

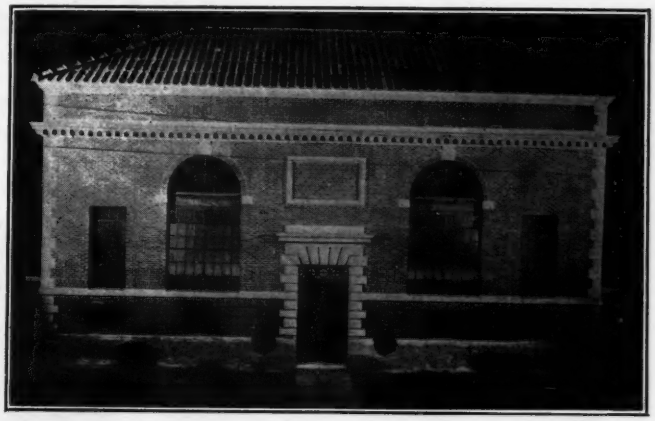
It may be well to mention that results as here given are probably a little more accurate and may not be easily checked, due to the fact that resistance values take into account skin effect, which is very appreciable in the larger sizes of conductor. Reactance values take into account stranding effect of the conductor. Resistance and reactance values were taken from Nesbit's Electrical Characteristics of Transmission Circuits. The tables in this publication are, without doubt, the most accurate of any tables that ever have been published.

| SIZE | DIA. IN. | 60 CY. RES. | WT. PER Mile LBS. | EQUIVALENT SPACING IN FEET | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1' | 2' | 3' | 4' | 5' | 7' | 9' | 11' | 13' | 15' |
| No. 8 H.D. Bare Copper | 0.1285 | 3.4737 | 264 | 0.663 | 0.748 | 0.796 | 0.832 | 0.859 | 0,900 | 0.929 | 0.954 | 0,974 | 0.992 |
| No. 6 " " " | 0.1840 | 2.2290 | 428 | 0.630 | 0.714 | 0.763 | 0.798 | 0.825 | 0.866 | 0.897 | 0.921 | 0.941 | 0.959 |
| No. 4 " " " | 0.2320 | 1.4020 | 680 | 0.602 | 0.686 | 0.735 | 0.770 | 0.797 | 0.838 | 0.869 | 0.893 | 0.913 | 0.931 |
| No. 2 " " " | 0.2920 | 0.8819 | 1080 | 0.574 | 0.656 | 0.707 | 0.742 | 0.769 | 0.810 | 0.841 | 0.865 | 0.885 | 0.902 |
| No. 1 " " " | 0.3280 | 0.6995 | 1360 | 0.560 | 0.644 | 0.693 | 0.728 | 0.755 | 0.796 | 0.826 | 0.851 | 0.871 | 0.888 |
| No.1/0" " " | 0.3680 | 0.5549 | 1720 | 0.546 | 0.630 | 0.679 | 0.714 | 0.741 | 0.782 | 0.812 | 0.837 | 0.857 | 0.874 |
| No.2/0" " " | 0.4140 | 0.4403 | 2170 | 0.532 | 0.616 | 0.665 | 0.700 | 0.727 | 0.768 | 0.798 | 0.823 | 0.843 | 0.860 |
| No.3/0" " " | 0.4640 | 0.3495 | 2740 | 0.518 | 0.602 | 0.651 | 0.686 | 0.713 | 0.754 | 0.784 | 0.809 | 0.829 | 0.846 |
| No.4/0" " " | 0.5220 | 0.2776 | 3450 | 0.504 | 0.588 | 0.637 | 0.672 | 0.699 | 0.740 | 0.770 | 0.795 | 0.815 | 0.832 |
| 250,000 CM " " | 0.5740 | 0.2354 | 4080 | 0.487 | 0.571 | 0.620 | 0.655 | 0.682 | 0.723 | 0.753 | 0.778 | 0.798 | 0.815 |
| 300,000 " " " | 0.6280 | 0.1966 | 4890 | 0.476 | 1.560 | 0.609 | 0.644 | 0.671 | 0.712 | 0.742 | 0.767 | 0.787 | 0.804 |
| 350,000 " " " | 0.6790 | 0.1690 | 5710 | 0.466 | 0.550 | 0.600 | 0.635 | 0.662 | 0.702 | 0.733 | 0.757 | 0.778 | 0.795 |
| 400,000 " " " | 0.7250 | 0.1484 | 6520 | 0.458 | 0.542 | 0.592 | 0.626 | 0.654 | 0.694 | 0,725 | 0.749 | 0.769 | 0.787 |
| 450,000 " " " | 0.7720 | 0.1324 | 7340 | 0.449 | 0.533 | 0.582 | 0.617 | 0.644 | 0.685 | 0.716 | 0.740 | 0.760 | 0.778 |
| 500,000 " " " | 0.8140 | 0.1197 | 8150 | 0.443 | 0.527 | 0.576 | 0.611 | 0.638 | 0.679 | 0.709 | 0.734 | 0.754 | 0.771 |

TABLE IV. RESISTANCE AND REACTANCE TABLE

# Beautification *of* Power Plants *and* Substations

*By P. S. Arkwright*



BEAUTIFICATION of the grounds of hydro electric generating plants, steam plants, substations and other utility properties not only performs magic in transforming what might easily become eyesores into places of beauty, but also has its economic value, as the Georgia Power Co. has discovered.

No longer does an announcement of the erection of a substation in Atlanta's residential districts arouse a storm of disapproval. Petitions are not circulated to block the construction of such buildings. Rather, the residents encourage the company to construct these stations.

An outstanding example of the company's use of beauty in substation construction as an instrument to obtain public good will is found in the case of the Spring Street substation in Atlanta. When the announcement was made that a substation was to be built on a boulevard in a high class residential section, owners of property employed every means to prevent the company from going forward with the plans; however, the substation was constructed. It is a noiseless, automatic station, set off in a plot of well-kept lawn and surrounded by shrubbery and flowers. At night, flood lights play on the building, attracting the attention of motorists, hundreds of whom pass the building every day. So dignified does the building appear that it has often been mistaken for a branch of the public library or a branch of one of Atlanta's larger banks.

Since the completion of the building and the landscaping of the grounds, the company has heard nothing but praise for the new building.

The landscaping and beautification of the Spring Street substation was not an experiment. For several years, the Georgia Power Co. has been as particular about the appearance of its buildings as it has about their mechanical behavior.

An attractive lawn, a flower bed, selected and well maintained shrubbery about a building are incentives to the men working at the plant. They will keep their machines neater and in better condition. They will work more efficiently because of the higher opinion they have of their work.

### Beautification in Charge of Landscape Gardener

A competent landscape gardener, a graduate of the agricultural engineering course at the state university, is employed by the company to beautify the properties of the company, but his work does not stop there.

Scarcely a week passes that a new city or town is not added to the company's lines. In most instances, the company is a stranger. In some cases, acts of the company are looked upon with suspicion, especially when the line crews start tearing down obsolete distribution systems which have served the community with varying degrees of satisfaction for years. Often the distribution lines are so entangled with trees that it is

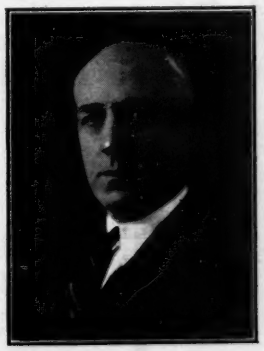


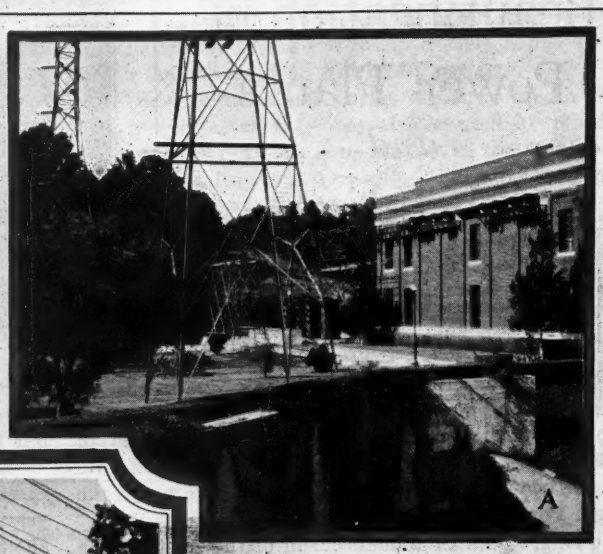
Photo by Blank-Stoller, Inc.

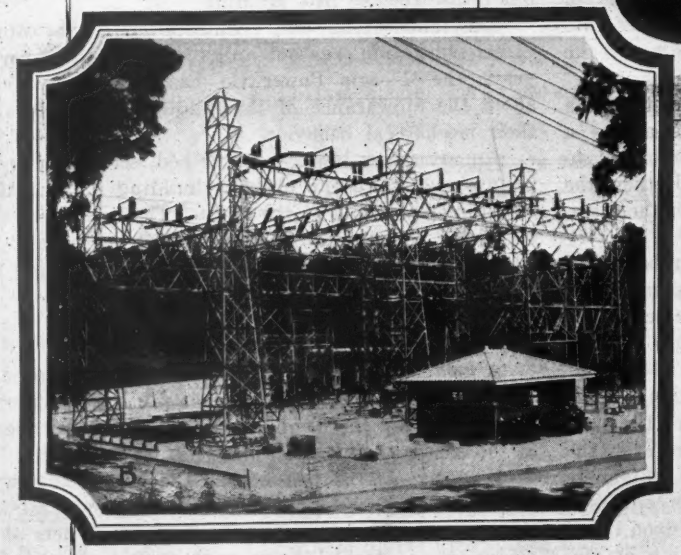
**Preston S. Arkwright**, president of the Georgia Power Co., is one of the foremost public utility men in the nation. He is first vice-president of the National Electric Light Association, vice-president of the Association of Edison Illuminating Companies, and former president of the Southern Gas Association.

Mr. Arkwright was born in Savannah, February 24, 1871. He prepared for college in the Savannah schools, and was graduated in law from the University of Georgia in 1891.

He entered public utility work in 1901, when he became vice-president of the Georgia Electric Light Co. In 1902 he was elected president of the Georgia Railway and Electric Co., and when the Georgia Railway and Power Co. was formed in 1912, absorbing the Georgia Railway and Electric Co. and other utility companies, he was elected president of the new company. This position he held until the Georgia Railway and Power Co. consolidated with about 20 other public utility companies in Georgia to form the Georgia Power Co. in 1927, Mr. Arkwright becoming president of the consolidated company.

Attractive Shrubbery and well kept lawns add materially to the appearance and value of these Georgia Power Co. Substations

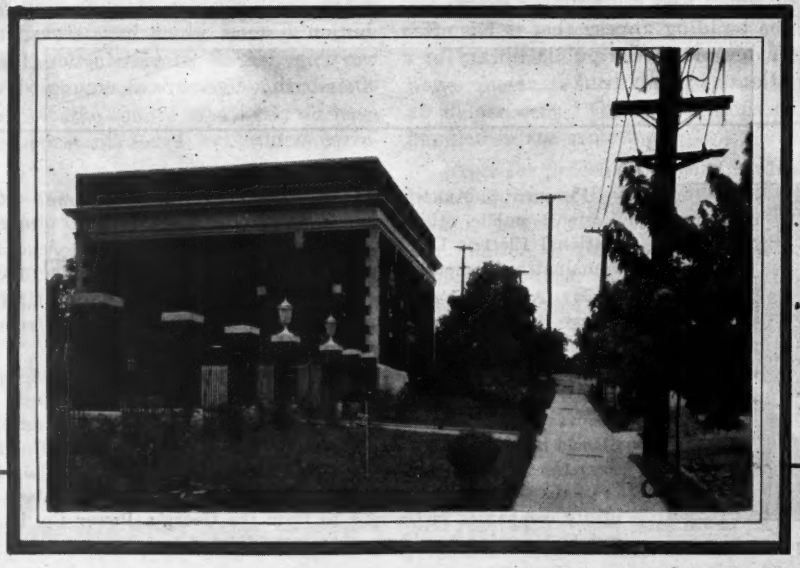



A. The grounds of the Boulevard substation are kept as attractive as those of any privately owned estate.

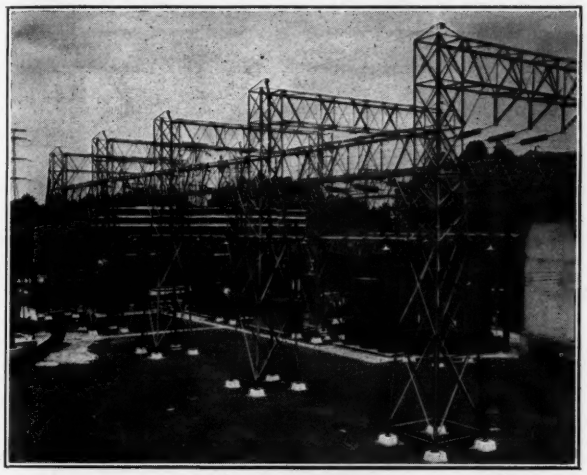
B. With its shrubbery and flower pots, Norcross substation is far from being an eyesore.

C. The Moreland Ave. substation, another fine example of ground beautification.



difficult to decide where the wires leave off and the trees begin. It is necessary in such cases to chop down the trees or cut off many of the branches when the new line is constructed. If the work is done by the line crew, the owner of the tree immediately becomes antagonistic toward the company, feeling that the company's employes are overstepping their rights in cutting down his trees. He may give his permission, but he continues to feel badly toward the company.

In such cases, the landscape gardener approaches the owner of the tree and explains the situation to him. As a competent tree surgeon, he supervises "operations" on the tree, "amputating" the boughs that interfere with the line. Often, too, the tree is sickly. The tree surgeon treats it and other trees in the yard, though they may not be in the way of the line. By following



A SWITCHING FRAME WAS NOT ESPECIALLY DESIGNED TO ADD TO THE BEAUTY OF THE NEIGHBORHOOD, BUT WHAT COMMUNITY WOULD OBJECT TO A STRUCTURE SUCH AS THIS, THE BOULEVARD SUBSTATION OF THE GEORGIA POWER CO.?

this plan, an act which would ordinarily cause ill will promotes good will.

In addition to this, the services of the landscaper are offered to communities, women's clubs, civic organizations and garden clubs. He has supervised several civic beautification programs, plotting out the location and type of shrub, flower plot or lawn that should be planted in a parkway, civic square, courthouse grounds or school house grounds. Practically all his work of this type has been carried on in the smaller towns. It has served as a favorable introduction for the company, and has gained much good will.

### Lawns Take the Place of Junk Heaps

At practically all of the company's properties, lawn plots and flower beds have taken the place of junk heaps. Machines, formerly grimy and greasy, are painted and a handsome appearance is maintained.

At the hydro-electric plants in the Blue Ridge mountains, the grounds are cleaned up as soon as possible after the plants are completed. Grass is sown, trees and shrubbery is purchased by the carload and planted in the nursery until needed to beautify some new plant or substation.

Work of beautification is not confined to the grounds of the plants, but is extended to include the beautification of the homes of employes who live near the plants in the mountains.

Where untidy construction camps once sprawled, a blemish on the beauty of northeast Georgia, handsome and well-planned communities inhabited by employes at the plants, are now located.

Dividends derived from beautification are large, in promoting good will, in increasing efficiency of employes and in satisfaction to the company in feeling that its buildings are assets to the community aesthetically as well as materially.

## North and South Carolina to Have Increased Power Facilities

Several important power and water projects are being arranged for early development in different sections of North and South Carolina, totaling, with important sewage projects, no less than 18 individual enterprises with total investment of more than $8,000,000. Among the largest developments are: a steam-operated electric power plant at River Bend, on the Catawba River near Mount Holly, N. C., with rated output of 150,000 hp. to be constructed by the Duke Power Co., Charlotte, N. C., to cost approximately $5,000,000; expansion program of the Carolina Electric & Gas Co. at Kinston, N. C., and vicinity, including new transmission lines and power substations, to cost more than $1,000,000; municipal power plant at Marshall, N. C., to cost about $90,000; new power substation and transmission lines of the Carolina Power & Light Co. at Marion, N. C., and vicinity, to cost $150,000; substation of last noted company at Sanford, N. C., to cost about $80,000; municipal waterworks at Kings Mountain, N. C., estimated to cost $250,000; extensions in municipal water system at Greensboro, N. C., to cost about $150,000; municipal water plant at High Point, N. C., $55,000; extensions in sewage system at last noted place to cost about $600,000; municipal waterworks at Robbinsville, N. C., $25,000; municipal waterworks at Cowpens, S. C., to cost about $35,000. The Department of Public Works, Charlotte, N. C., is projecting plans for a new pipe line from the Catawba River to the city, for the municipal water system, at an estimated cost of $500,000.

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Northern Nebraska Power Co., Omaha, Neb., is planning another hydro-electric plant on the Niobrara River, costing $1,500,000. Power from this unit will be distributed over Nebraska, Iowa, the Dakotas and Minnesota. A sand fill and concrete dam will be built to give a 50-ft. waterfall. E. A. Forbes, president of the company, announcing plans for the development of the Niobrara power possibilities, said that experience with plants on that river showed that it presented unusual opportunities for power development.

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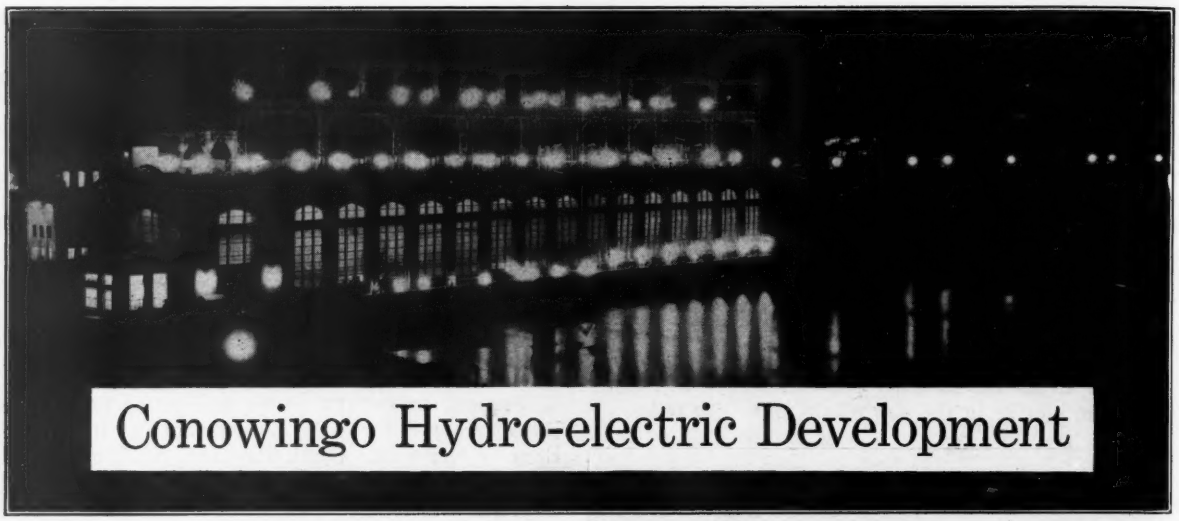
Compiled from the reports of 12 establishments, the report of the Department of Commerce for April shows a total of 88 stokers sold, installed under 31,043 hp. of boilers. Of this number 21 are under 3,081 hp. of fire-tube boilers and 67 under 27,962 hp. of water-tube boilers.



# Conowingo Hydro-electric Development

EXCEPTIONAL SPEED OF CONSTRUCTION FEATURE OF GREAT SUSQUEHANNA RIVER DEVELOPMENT. FIRST UNITS ON LINE 3 MO. AHEAD OF SCHEDULED TIME

WITH AN INITIAL installation of 378,000 hp. in seven main units, ultimately to be increased to 594,000 hp. in 11 units, the Conowingo development ranks as one of the largest hydroelectric projects in the United States. This development consists of a power house and dam across the Susquehanna River near Conowingo, Md., designed to develop the fall of the river from the tailrace of the Pennsylvania Water & Power Co.'s dam at Holtwood, Pa., to a point within 4 mi. of tidewater. From the standpoint of speed of construction, Conowingo is an outstanding achievement, requiring less than 2 yr. from the start of construction operation to regular operation of the first unit.

Conowingo is controlled by the Philadelphia Electric Co. through its subsidiary. Since the Philadelphia Electric Co. will use practically the entire output of Conowingo development, it was necessary that it should control the operation of the plant. Its charter, however, does not permit it to hold titles or property in Maryland, so the requirements were met by the organization of three subsidiary or otherwise controlled corporations as follows:

The Susquehanna Power Co., incorporated in Maryland, to hold titles to all the physical properties of the project located in that state, including the dam, power house and tailrace and portions of the reservoir and transmission line.

Philadelphia Electric Power Co., incorporated in Pennsylvania, to hold titles to all physical properties of the project located in Pennsylvania, this being principally land for the reservoir and the greater portion of the transmission line.

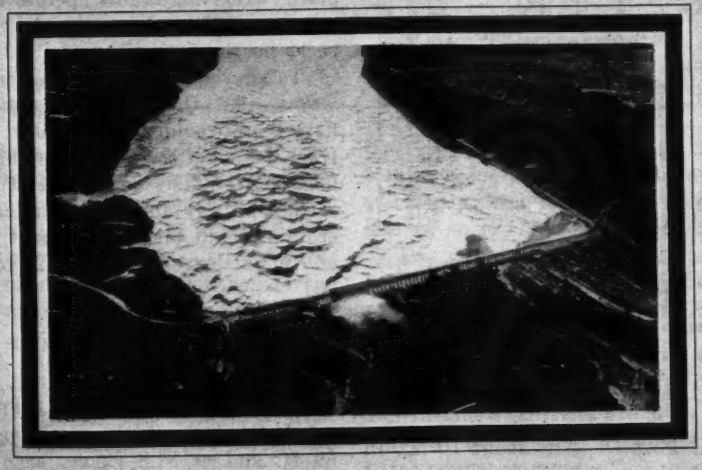
The Susquehanna Electric Co., which has leased for the term of the federal license the properties of the Susquehanna Power Co. in Maryland. This subsidiary, under contract with the Philadelphia Electric Co., operates the plant and sells the generated energy to the Philadelphia Electric Co. As set up, therefore, the Conowingo Hydroelectric development has been made by and for the Philadelphia Electric Co. and is being operated as a part of that company system.

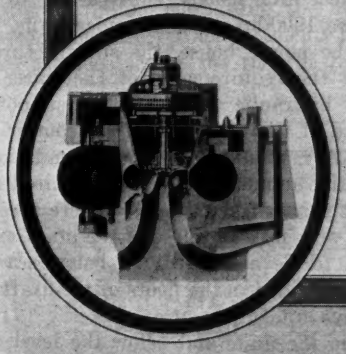
Before describing the engineering features of the project, it will be interesting to learn a few facts regarding the river on which the project is situated. With the exception of the St. Lawrence, the Susquehanna River basin is the largest and most important on the Atlantic Coast. Its total area of 27,400 sq. mi. includes 47 per cent of the total area of the state of Pennsylvania, 13 per cent of the total area of the state of New York and 2 per cent of the total area of the state of Maryland, extending north almost to Utica, N. Y., and west beyond Altoona, Pa. The annual precipitation over the area drained by this great river, according to records of the United States Weather Bureau, varies from 31.4 in. to 44.3 in. with a mean of 39.4 in. The run-off, which eventually finds its way to the sea through the Susquehanna River, varies from 16.6 in. to 29.1 in. and averages 55 per cent of the rainfall. The run-off is at a minimum in August, September and October, during which months it ranges from 5 per cent to 30 per cent of the rainfall and averages about 15 per cent. The flow is extremely variable. It is this feature, in fact, more than any other, which has prevented the construction of a power plant on the Conowingo site earlier. Large scale power development was not economically feasible until electric demand in nearby centers served from steam-driven generating equipment had become capable of absorbing the hydro power available during high flow periods. This condition is now met by the load of the Philadelphia Electric Co. system.

## SITE OF DAM

Conowingo Dam is located at a point of the river where the hills on either side form natural abutments. Core borings drilled along the line of the upstream face of the dam to depths varying from 5 ft. to 100 ft. below the rock ledge all showed firm hard rock for their entire length. As the main channel of the river ran along the Harford County shore, the power house was located at this end of the dam. The building of the dam forms a lake approximately 14 mi. upstream to the tailrace of the Holtwood plant of the Pennsylvania Water & Power

# Interesting Views at Conowingo





Co. At normal and maximum elevation of 108.5 ft. above sea level the area of the pond will be about 8600 acres.

Since the former location of the Columbia and Port Deposit branch of the Pennsylvania Railroad along the east bank of the Susquehanna River has been submerged, a new road bed was provided above the 108.5-ft. pond level from just below Holtwood to the dam and below the dam dropping down at a maximum of 0.35 per cent

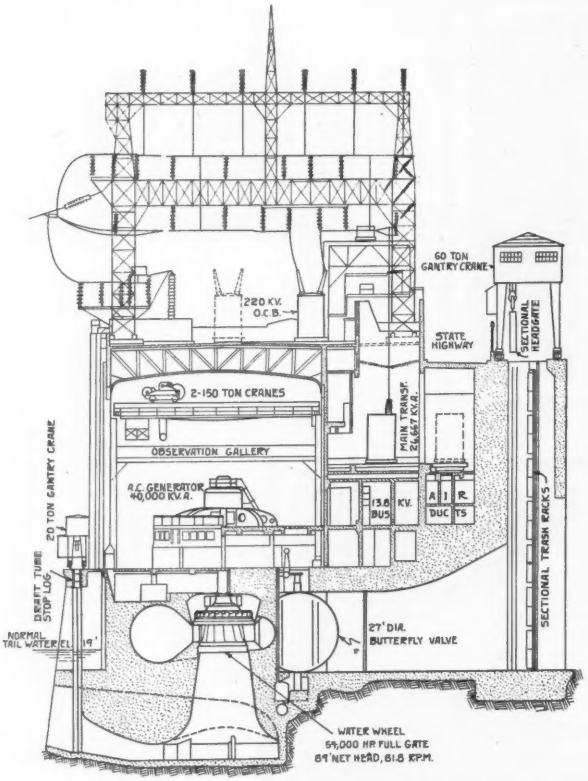



FIG. 1. TWO-HUNDRED-AND-TWENTY THOUSAND-VOLT SWITCHING STRUCTURE IS LOCATED ABOVE GENERATOR ROOM

to the original grade at Port Deposit, about 16 mi. in all. The Philadelphia-Baltimore pike has been relocated so as to cross the river on a bridge placed on top of the dam structure.

## Design of Dam and Headwork

Conowingo Dam is of solid concrete masonry construction designed as a gravity section. Its total length, 4648 ft., includes the power house headwork, 950 ft. long and 2385 ft. of Ogee-type, gate controlled, stairway sections. To collect seepage water under the dam and prevent excessive uplift, a longitudinal drain was installed on the foundation 10 ft. 6 in. downstream from the base of the dam. Cross drains spaced 45 ft. on centers connect this drain to tail water at the toe of the dam. Riser drains at all vertical construction points connect the bottom drains to the inspection tunnel. To reduce seepage through the vertical construction joints copper sealing strips were installed near the upstream base of the dam. Grout holes located 2 ft. inside the upstream base of the dam were drilled in the foundation to a depth of 20 ft. at 10-ft. intervals and grouted under 25-lb. pressure to form a cutoff wall against seepage through the foundation.

An unusual feature of the spillway section is the overhanging crest. This permitted a curved surface approximating the lower nappe of an overflowing stream of the depth of 22.5 ft. to be formed without increasing the width of the section beyond that required for stability. The crest of the main spillway is fixed at elevation 86 and is surmounted by 50 Stony type movable crest gates, each 22.5 ft. high by 41 ft. wide, operating in guides provided in concrete piers on the dam. Three regulating gates, each 10 ft. high by 41 ft. wide, have been provided adjacent to the power house on a fixed crest at elevation 98.5 for use in finer regulation of the pool level. In the design of the spillway, an allowance of 4000 lb. per linear foot was assumed for ice pressure at the water surface. A compressed air system, discharging air below the water surface upstream from the gates, has been provided to prevent formation of heavy ice against the gates. Electric heaters have also been provided to keep the gate guides free from ice. The gate piers, spaced 45 ft. on centers, continue up above the pool level and support a runway at elevation 115, extending along the spillway section and power house headwork from which three electrically-operated gantry traveling cranes operate the crest and regulating gates as well as the sectional head gates and the trash racks on the power house.

To prevent erosion at the toe of the dam, the spillway section, three regulating gates and 17 crest gates have been provided with a 20-ft. wide apron curving up from the toe of the dam to an angle of 12.5 deg. with the horizontal. Tests conducted at Worcester on a model of the spillway and apron indicated that the maximum erosion would take place about 150 ft. beyond the toe and might leave a depth of 25 or 30 ft. below the river bed.

## Power House Structure and Hydraulic Equipment

Seven generating units are provided in the initial installation. These are 54,000-hp. Francis runner vertical shaft water wheels, operating under normal head of 89 ft. and at 81.8 r.p.m., each direct connected to a 40,000-kv.a., 3-phase, 60-cycle, 13,800-v. generator.

These water wheels, generators and valves are the largest in physical dimensions constructed to date. There are also two 1900-hp. station service units.

In building the power house, the substructure was designed to meet the requirements of the water ways required by the hydraulic units and to support the superimposed load of the water wheel and power house superstructure. A maximum depth of foundation excavation to elevation minus 20.5 ft. was required at the hydraucone draft tubes of the wheel. Where spreading type, draft tubes were used on three of the units, excavation was carried to elevation 15.5 ft. below sea level. Weep holes were provided in the floors of the draft tubes to relieve excessive uplift pressure.

Upstream from the units and below the level of the scroll cases is an inspection tunnel from which access is afforded through each draft tube and to the butterfly valve thrust bearing on the unwatering system. Seepage through construction joints in the substructure and

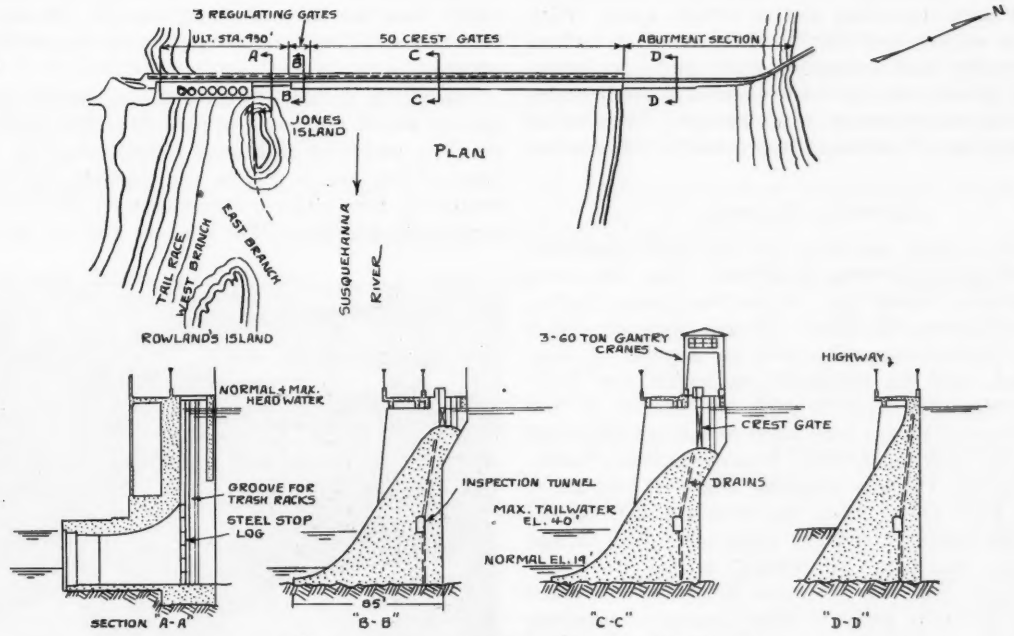



FIG. 2. GENERAL PLAN AND DAM SECTIONS

headwork is collected in a trench running in the inspection tunnel and drained to a sump at the west end of the power station where two small pumps are provided. Below this tunnel is a 42-in. cast-iron unwatering header, draining to a drain pump of large capacity located at the shore end of the station, served by two 15,000-g.p.m. pumps. Each draft tube, scroll case and intake upstream from the butterfly valve is connected to this unwatering header through suitable valve control piping so that this pumping installation can be used to unwater any one unit if desired. The main power station superstructure of the initial installation includes the generator room, which is about 70 ft. wide by 75 ft. high by 650 ft. long. The electrical bay between the generator room and headwork is a three-story building containing the 13,800-v. bus and switch compartments. Compartments for step-up transformers are located on the roof of the electrical bay, together with the main control room and station service control room, from which windows afford a direct view of the generator room. The 220-kv. switching station is located on the roof of the generator room.

In the generator room seven water wheels are connected to generators of different manufacture. All water wheel runners have been designed with the same clearance dimensions and the same number of speed ring bands and die bands. The waterways have the same general dimensions and the valve control mechanism and various auxiliaries are alike. As the runners of the different manufacturers are interchangeable, only one spare runner is required.

Four water wheels have draft tubes of the hydraucone type. Spreading draft tubes have been constructed for the other three water wheels. The governors are of the actuator type with flyballs driven through gears from the main shaft, and are operated by oil-pressure

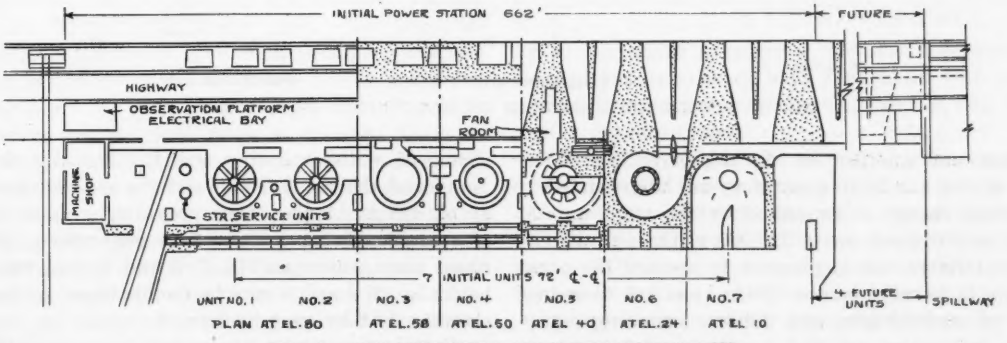



FIG. 3. ARRANGEMENT OF UNITS IN STATION

cylinders. There is one oil pressure system for each pair of units. An oil storage and purification system has been provided for all of the governors and bearing oil of all units, including station service units. With each main water wheel unit, a 27-ft. diameter vertical shaft butterfly valve complete with operating equipment, oil pressure system and accessories has been installed at the water passage to the runner. These valves are operated by oil pressure from a central oil pressure system.

### Electrical Features

Because of their enormous size, the main generators at Conowingo are of unusual interest. They are rated at 40,000 kv.a., 36,000 kw., 90 per cent power factor, 13,800 v., 3 phase, 60 cycles. Though there are others of larger kilowatt capacity, yet, on account of their slow speed, these are physically the largest ever built. They are provided with 88 poles and operate at 81.8 r.p.m. Mounted on the same shaft and above the thrust bearing is a 715-kv.a., 500-kw., 70 per cent power factor, 440-v., 3-phase, 60-cycle generator and a 41-kw., 250-v. exciter. Four of the units are provided with spring type thrust bearings and the other three with Kingsbury thrust bearings. The designs of the two manufacturers who built the generators have been so worked out that the units have the same general dimensions, which adds materially to the appearance of the generator room. The neutrals of both the main and auxiliary generators are brought out for differential relay protection and in the case of the main generators are then grounded through a four-ohm resistor, which is common to all of the units, even though the generators are separated from one another on the 13,800-v. side. The neutrals of the auxiliary generators are ungrounded.

Electrical energy is generated by the main unit at 13,800 v. and stepped up to 220,000 v. through 80,000-kv.a. transformers. It is planned to operate the plant as a whole in parallel on the 220-kv. bus but to reduce the cost of transformers and 220-kv. switching equipment two generators are tied together and to a transformer bank, thus forming an 80,000-kv.a. group. Thus, ultimately, if such operation is satisfactory, there will be six such groups parallel only on the 220-kv. side except that the last one (generator No. 11 and transformer No. 6) will necessarily be of but 40,000-kv.a. capacity.

Should it, at some future time, be deemed desirable for any reason to operate in parallel on the 13.8-kv. side, then, by means of additional construction, the various buses of this voltage may be tied together, some through reactors to form either a four-section ring bus or a three-section straight bus. The reactors may be cut out by means of a disconnecting switch. Initially the No. 3, No. 4 and the No. 5, No. 6 sections are tied together by an oil circuit breaker, thus providing greater flexibility of operation between these four generators. It will be noted that generators No. 3, 6 and 9, and transformer banks No. 2, 3 and 5 may be double bused in the future, should a 13.8-kv. ring be formed.

Station auxiliaries are served by a separate 440-v.,

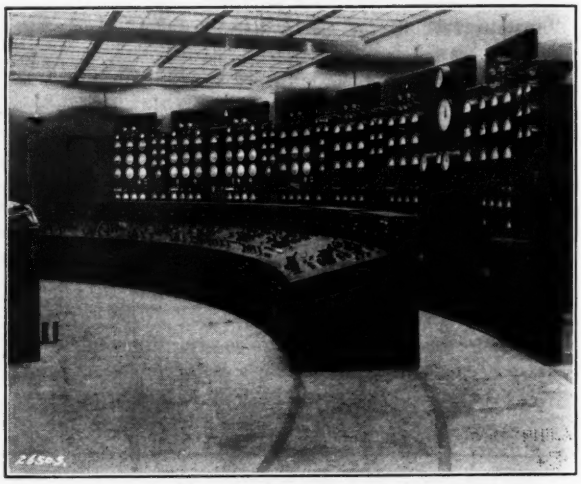


FIG. 5. MAIN CONTROL ROOM

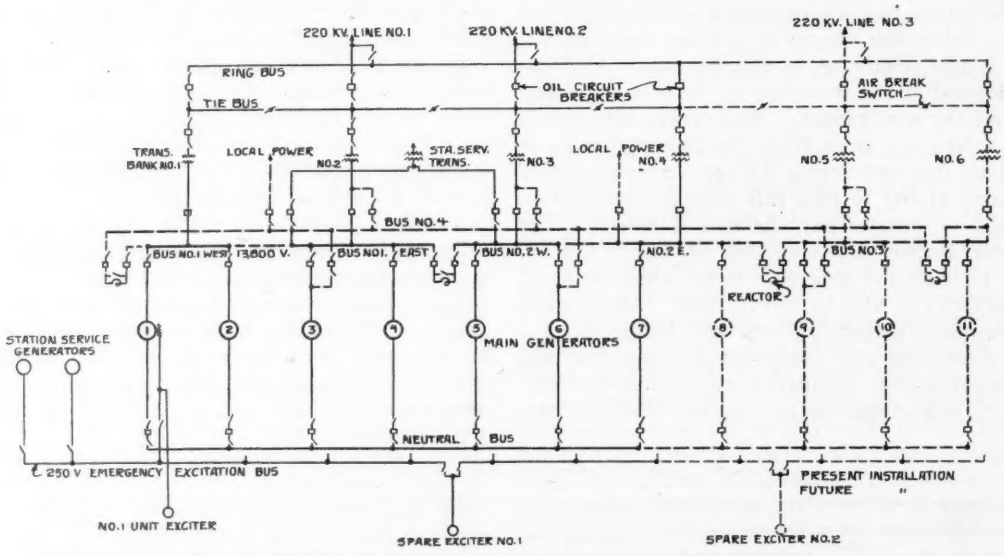



FIG. 4. SINGLE LINE DIAGRAM OF ELECTRICAL EQUIPMENT

3-phase system which may be divided into two parts: first, that to supply the essential auxiliaries of each main unit; and second, that to supply the less essential auxiliaries and the general lighting of the plant. The supply for the essential auxiliaries of each main unit is obtained from alternators which, together with their exciters, are directly connected on the shaft of the main unit. The supply for the less essential auxiliaries is obtained from two 1600-kv.a. station service turbine generators with direct connected exciters and a 2500-kv.a. station service transformer bank. The essential auxiliaries associated with each main generator unit are an exciter set, a governor oil pump and a generator ventilating fan.

Excitation for the main units is obtained from individual motor generator sets. These consist of a 375-hp. induction motor, a 240-kw., 250-v. main exciter and a 10-kw., 240-v. pilot exciter operating at 1200 r.p.m. In designing the excitation system, consideration was given to having the exciters mounted on the same shaft with the main unit but, due to their capacity and the slow speed, an extensive exciter of quite large dimensions and of slow response would have resulted if they could have been satisfactorily built. As high-speed excitation was essential for stability of operation, it was necessary to use motor generator exciters.

### Conclusions

Before beginning construction about 3 yr. ago, a progress schedule was carefully worked out to determine the progress necessary to be made by the various operations of the works to co-ordinate these operations with the stream of river diversion. This schedule contemplated operation of the first two units on June 1, 1928. Construction progress, however, was considerably better than scheduled, with the result that two units started commercial operation on March 1, and the third unit a few days later.

The following quantities involved in the construction of the dam and power house will be of interest: Coffer dam crib—4,250,000 cu. ft., rock excavation, including tailrace—348,000 cu. yd., forms—3,850,000 sq. ft., concrete—660,000 cu. yd., structural steel—9500 t., reinforcing steel—6400 t., hydraulic machinery 6500 t.

A maximum working force of 5300 men was employed on the project.

## Principal Equipment at Conowingo

### Dam, Power House and Tailrace

Stone and Webster, Inc.—Engineers and constructors.
The Arundel Corporation—Subcontractors for the dam.

### Relocation of 16 Miles of Columbia and Port Deposit Branch of Penna. R. R.

The Arundel Corporation.

### Transmission Line

Day and Zimmermann Engineering and Construction Company.

### Main Power House Equipment and Manufacturers

4—54,000-hp. water wheels—Allis-Chalmers Manufacturing Co.
3—54,000-hp. water wheels—Wm. Cramp and Sons Ship and Engine Building Co. (I. P. Morris Corp.)
2—1900-hp. station service water wheels—S. Morgan Smith Co.
4—40,000-kv.a., 13,800-v. generators—General Electric Co.
3—40,000-kv.a., 13,800-v. generators—Westinghouse Elec. & Mfg. Co.
2—1600-kv.a., 460-v. station service generators—Westinghouse Elec. & Mfg. Co.
13—26,667-kv.a. transformers (13.8/220-kv.)—General Electric Co.
3—833-kv.a. transformers (13,800/460-v.) station service—Westinghouse Elec. & Mfg. Co.
11—Oil circuit breakers (13,800-v.)—General Electric Co.
2—220-kv. lightning arrestors—General Electric Co.
8—240-kw. motor generator exciter sets—Westinghouse Elec. & Mfg. Co.
17—Special generator voltage regulators—Westinghouse Elec. & Mfg. Co.
Crest gates, regulating gates, sectional headgates, stop logs, trash racks, guides, etc., total of 5500 t.—Newport News Shipbuilding and Dry Dock Co.
Roller trains and latching equipment—M. H. Treadwell Co., Inc. (344 t.)
5—Electric traveling cranes (two 150-t. two 50-t. and one 15-t. capacity)—Niles Crane Corp.
3—60-t. Gantry cranes—Morgan Engineering Co.
1—20-t. Tailrace crane—Morgan Engineering Co.

### Auxiliary Equipment

14—Ventilating fans for generators and electrical bay—B. F. Sturtevant Co.
Elevator for office bay—Gurney Elevator Co.
4—Air compressors (two 200 lb. pres., 50 c.f.m.; two 100 lb. pres., 300 c.f.m.)—Worthington Pump and Machinery Corp.
2—Control and emergency lighting batteries—Electric Storage Battery Co.
3—Battery charging motor generating sets—General Electric Co.
2—49-hp. horizontal return tubular heating boilers—Titusville Iron Works.
Bus supports, disconnecting switches, fuses and resistor mountings and inserts—Electric Power Equipment Corp.
190,000-ft. galvanized conduit—The Philadelphia Electric Co. Supply Department.
440-v. station service and exciter switchboard—Cutler Electric and Mfg. Co.
47,000 lb. bus bar copper—The American Brass Co.
Filtered water plant and equipment—Norwood Engineering Co.
Fire alarm equipment—The Gamewell Co.
3—Foamite chemical engines and
2—Foam generators—Foamite-Childs Corp.
Heating and ventilating duct system—Riggs-Distler and Company, Inc.
1—Generator rotor lifting beam (300 t. capacity)—Alliance Machine Co.
1—440-v. induction regulator—Westinghouse Elec. & Mfg. Co.
Oil purification equipment—The Sharpless Specialty Co.
6—15,000-gal., one 11,000-gal. and one 2000-gal. oil tanks—R. S. Newbold and Son Co.
2—Pumps and filtered water system—Quimby Pump Co., Inc.
2—Fuel oil and one circuit oil pumps—Kinney Manufacturing Co.
2—15,000-g.p.m. unwatering pumps—Worthington Pump and Machinery Corp.
1—Heating return vacuum pump—Nash Engineering Co.
2—Transformer cooling water pumps—Ingersoll-Rand Co.
3—Transformer oil pumps—Worthington Pump and Machinery Corp.
Switchboard and generator room signal equipment—Q. P. Signal Co.
Safety switches for 440-v. installation—Westinghouse Elec. & Mfg. Co.
Main switchboards—The Philadelphia Electric Co.
Miscellaneous valves—Walworth Co., Ohio Injector Co., H. Belfield Co.
Ventilating fan motors—Westinghouse Elec. & Mfg. Co.
6—Electric drinking water coolers—Kelvinator, Inc.
Water level recorders and indicators—Leupold-Volpel and Co.
Rubber insulated wire and cable—The Philadelphia Electric Supply Dept., Standard Underground Cable Co.

### Power House Building

Structural steel for power house, highway and dam, and gantry runways (5700 t.)—Fort Pitt Bridge Works.
Steel sash (22,000 sq. ft.), skylights and ventilators—David Lupton's Sons Co.
Roofing and sheet metal—Thomas S. Gassner Co.
Doors and frames—Howell, Field and Goddard, Inc.
Bus compartment doors—Horricks Iron Works.
Terrazzo floor—American Tile and Cement Co.
Glass and glazing—Pittsburgh Glass Co.
Hardware—Murta, Appleton and Co.
Lighting fixtures—Edward T. Caldwell and Co.
Mechanical sash operators—Lord and Burnham Co.
Plastering—John H. Hampshire.

### Switching Station on Roof of Power House

7—220-kv. oil circuit breakers—Westinghouse Elec. and Mfg. Co.
Structural steel arbor (400 t.)—Blaw-Knox Co.
13—220-kv. disconnect switches—Railway and Ind. Engineering Co.

### Transmission Line and River Crossing

Towers, transmission line, 6000 t.—Blaw-Knox Co.
Towers, river crossing, 275 t.—Archbold-Brady Co.
Insulators-suspension discs, 13,000 pcs.—Westinghouse Elec. & Mfg. Co.
Insulators-suspension discs, 13,000 pcs.—Lapp Insulator Co.
Conductors (795,000-c.m.), aluminum core, steel reinforced, 352 mi.—Aluminum Co. of America.
Ground wire (184,000 c.m.), aluminum core, steel reinforced, 235 mi.—Aluminum Co. of America.

# High-Pressure Steam Boilers*

Discussion of Principles Underlying Their Design and Construction. By Geo. A. Orrok†

IN STUDYING the various designs of tubular boilers it appears that most of the water content of a boiler is contained in the tube bank, the drums rarely containing as much as 15 per cent of the total water content. In general, the weight of water in a boiler with 1-in. tubes will not exceed 0.9 lb. per sq. ft. of heating surface, which increases to about 3.5 lb. per sq. ft. of surface for the standard 4-in. tube and is directly proportional to the internal diameter of the tube. Multiple drums, outside downcomers, large mud drums, and water-wall headers may increase these figures.

down with an increase of pressure, and advances the opinion that "insufficient water circulation at very high pressures is not to be expected."

We may take it as a fact that with water-tube boilers, circulation may be rapid or sluggish, depending on the arrangements which the designer has used, and that the more nearly the boiler approaches the flash type, the slower is the circulation. As a corollary to this conclusion, we can state that the water content of a boiler and the necessity for speed in circulation increase with the departure in type from the flash boiler and must be

DATA ON MODERN BOILERS

| Types of boilers and drum sizes | SS Steam space, cu. ft. | RS Releasing surface, sq. ft. | HS Heating surface, sq. ft. | HS/RS | HS/SS | Weight of water in boiler, lb. | W/HS | W Water evaporated per hour, lb. | Time to evaporate boiler content, min. |
|---|---|---|---|---|---|---|---|---|---|
| **Steam Pressure, 200 Lb. per Sq. In.** | | | | | | | | | |
| Belleville (S.S. *Charlemagne*), 20 in. × 7 ft. 6 in., 7 elements, 16 tubes | 16.5 | 0.61 (*a*) | 1,800 | 2950 | 109 | 3,500 | 1.95 | 14,220 | 14.7 |
| Ward (U.S.S. *Monterey*) | 18.0 | 0.45 (*a*) | 2,970 | 6670 | 165 | 5,360 | 1.81 | 20 100 | 16.0 |
| B. &. W. (U.S.S. *Cincinnati*), cross-drum 42 in. × 12 ft | 58 | 42 | 2,640 | 63 | 45.5 | 9,480 | 3.59 | 30,760 | 18.6 |
| Stirling (Connors Creek), two 48 in. and 154 in. × 28 ft. | 576 | 350 | 25,000 | 71 5 | 43.4 | 66,000 | 2.64 | 149,600 | 26.5 |
| Almy, 66, 1¼-in. tubes | 37 | 0.47 (*a*) | 1,386 | 2950 | 37.5 | 1,850 | 1.34 | 3,230 | 34.0 |
| B. & W. (Dayton), cross-drum 60 in. × 26 ft | 255 | 130 | 12,500 | 96.3 | 49 0 | 84,240 | 6.75 | 91,200 | 55.4 |
| B. & W. (Waterside), three 42 in. × 20 ft. | 288 | 210 | 6,500 | 31 | 22.5 | 51,210 | 7.88 | 54,900 | 56.0 |
| Return tubular, 60 in. × 18 ft., 125 boiler hp. | 70 | 76 5 | 1,250 | 16 6 | 17.9 | 16,100 | 13.4 | 5,620 | 171 |
| **Steam Pressure, 250–400 Lb. per Sq. In.** | | | | | | | | | |
| Ladd (Fordson plant), 7-drum 60 in. × 27 ft., 54 in. × 28 ft., 36 in. × 25 ft. | 1151 | 522 | 29,500 | 56.5 | 25.6 | 206,000 | 7.0 | 97,000 (*b*) | 128 |
| | | | | | | | | 460,000 | 27 |
| B. & W. (Colfax), cross-drum 60 in. × 33.7 ft., 20 × 47 tubes. | 330 | 165 | 29.780 | 181 | 90.5 | 113,000 | 3.8 | 98,000 | 69 |
| | | | | | | | | 300.000 (*b*) | 22.5 |
| B. &. W. (Gould St.), cross-drum 60 in. × 32.8 ft., 18 × 51 tubes. | 321 | 161 | 29,070 | 181 | 90.5 | 106,000 | 3.65 | 104,000 | 61 |
| | | | | | | | | 416,000 (*b*) | 15.3 |
| B. &. W. (Stanwix), cross-drum 60 in. × 33.7 ft., 20 × 51 tubes. | 330 | 165 | 32,070 | 194 | 97.0 | 119,000 | 3.72 | 105,000 | 68 |
| | | | | | | | | 300,000 (*b*) | 24 |
| Springfield (Hell Gate), cross-drum 54 in. × 29.5 ft., 16 × 54 tubes | 235 | 133 | 13,900 | 104 | 59.2 | 70,000 | 5.04 | 225,000 | 18.7 |
| Springfield (East River), cross-drum 54 in. × 29.5 ft., 16 × 54 tubes | 231 | 133 | 17,830 | 134 | 77.2 | 103,000 | 5.78 | 350,000 | 17.7 |
| **High-Pressure Boilers, 1200–3200 Lb. per Sq. In.** | | | | | | | | | |
| Atmos., element, 12 in. × 15 ft | 3.0 | 23.5 | 47 | 2 | 15.7 | 425 | 9.1 | 2,500 | 10.0 |
| Schmidt-Hartmann (SHG), 36 in. × 10 ft. 10 in. | 20.7 | 29.0 | 283 | 9 8 | 13.7 | 2,320 | 8 2 | 3,300 | 42.0 |
| Benson (SSW) | 0 | 0 | 1850 | ∞ | ∞ | 680 | 0.37 | 66,000 | 37 sec. |

(*a*) Water level in tubes.
(*b*) Evaporation at 100 per cent of rating and maximum evaporation.

Only a few experiments have been made to determine the tube slope for maximum efficiency, and such experiments as have been made are not conclusive. As a matter of fact, equivalent efficiencies have been obtained with tubes of practically all degrees of slope.

## Circulation

Some authorities have figured maximum velocities in tubes of Babcock & Wilcox type boilers in excess of 100 ft. per sec., but it is safe to assume about 20 ft. per sec. as about the usual maximum. Unpublished tests available to the author show up to 50 ft. per sec. in vertical tubes and up to 40 ft. in tubes whose slopes approach the horizontal. In certain other types of boiler, such as the Almy or Ward and the Belleville, conditions approximating the flash boiler exist, and the water circulates only once through the tubes. Munzinger shows that the water circulation of necessity slows at their maximum in a shell boiler.

This leads to the Benson contention that the best results should be obtained at the critical point (3200 lb.) where steam and water have the same density, therefore no bubbles exist and no line of demarcation can be drawn between water and steam.

## Releasing Surface and Steam Space

It is usually stated that there must be a water surface of sufficient area to release the steam bubbles from the water to prevent priming and that a steam-storage space must be provided to allow the water particles not evaporated but entrained in the steam to settle out. The usual allowance for steam space in a shell boiler is about one-third of the volume and the ratio of heating surface (HS) to releasing surface (RS) is HS/RS = 3.5. This ratio in the ordinary return-tubular boiler is 17, in the standard three-drum, 14-high 21-wide, Babcock & Wilcox is 31, in the Babcock & Wilcox cross-drum type, 96; in the Connors Creek Stirling, 71; and in the Almy, Ward and Belleville types, from 2000 to 7000. As

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all of these boilers prime occasionally and all can be run without priming, it will be seen that the releasing surface has nothing to do with priming.

Efficient dry pipes are an essential part of all boilers, and the greater capacity (higher rating) obtained requires a better and more liberal design of dry pipe. Steam domes and steam drums in addition to the ordinary drum have been used to assist in obtaining dry steam. Superheaters should not be used for evaporators, and the releasing surface should be such that particles of water under maximum conditions should not reach the dry pipe.

The steam-space ratio (HS/SS) also varies largely —from about 4-in. shell boilers, 22.5 in the longitudinal-drum Babcock & Wilcox, and 50 in the Babcock & Wilcox cross-drum to over 100 in the Belleville and 150 in the Ward, and was very large in the earlier Belleville boilers and almost infinity in the Herreshoff coil boiler and other flash boilers. All of the high-ratio boilers made special provisions for feedwater regulators and safety valves, and these features appear to be necessary for operation.

At 200 lb. gage the figure is roughly 3 sq. ft. per 1000 lb. per hr., while at 1200 lb. the surface is 0.5 sq. ft. per 1000 lb. evaporated per hour. Considering the 200-lb. boilers (in Table I), the 3 sq. ft. per 1000 lb. per hr. is 5 cu. ft. of steam per sq. in. of releasing surface per hour. The table shows normal values of ten times this ratio at 100 per cent of boiler rating.

### Safety in Operation

As a general rule, that design is the safest which has the smallest volume of water content, since "superheated water" is the chief source of danger in a boiler; therefore drums should be made as small in diameter as possible in order to avoid this danger. The tearing of drum sheets, so common in explosions of low-pressure boilers, allowing large volumes of superheated water to flash into steam, should not occur in high-pressure work. It has been observed by all operators of high-pressure boilers that split tubes or bulges which open do not lead to explosions.

### Increase in Capacity

The most important development in boilers in the twentieth century is the great increase in capacities which are now being secured from all types of modern boilers. Fifteen to twenty pounds at good efficiency has now been secured and 25 to 30 lb. is in sight. This condition exaggerates an operating difficulty more or less common in earlier boiler plants, namely, the "loss of water" or the lowering of the water level in the boiler drum below the gage-glass level when the forced draft failed or the coal feed was interrupted in the powdered-coal installations.

In most modern boilers less than 15 per cent of the water is contained in the drum, and when steaming at a high rate more than 20 per cent by volume of the water is steam bubbles. As long as the operation is continuous, no troubles are encountered but in an emergency when the coal feed is interrupted or the forced draft is cut off, the bubbles are absorbed and the water contracts rapidly, the water level falls and the automatic feed regulators open wide, filling up the drum. When steam making starts, the volume increases, the water level rises, water enters the dry pipe and slugs of water may pass through the superheater and steam mains with serious results. In flash boilers and boilers above 600 lb. pressure, this difficulty is not of much moment but at pressures from 200 to 600 lb. and high ratings, as much as 40 per cent contraction may be encountered and the water level brought well down into the tube body.

Fatigue phenomena are apparently reasonably consistent and only rarely enter into the boiler problem. Creep phenomena, on the other hand, are still highly controversial, some authorities holding that creep does not occur below certain limited stresses which may be well above the limits of proportionality. The opposing

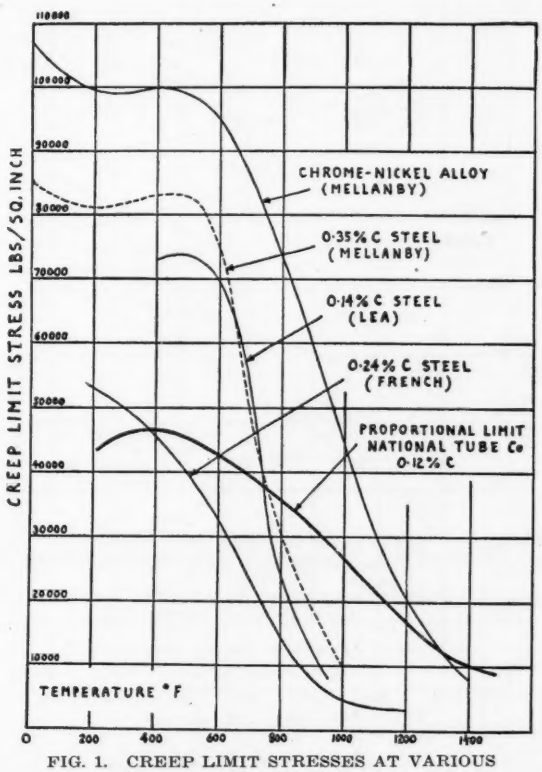



FIG. 1. CREEP LIMIT STRESSES AT VARIOUS TEMPERATURES

theory that creep occurs at all temperatures and stresses and that the condition must be chosen to limit the creep to safe values over a period of time, is also strongly held. Mellanby, Lea, Tapsell and others in England and France, and Lynch, Malcolm, McVetty, White and others in America, have presented excellent papers in which the known facts and theories have been ably discussed The diversity of opinion is best shown by the curves of Fig. 1, where curves obtained from various boiler materials are shown. Since the "creep limit" is usually placed at or around the proportional limit, or perhaps the yield point, or something around these figures, the actual yield point of tube steel as manufactured by the National Tube Co. is also included. From many observations of actual boilers, the author's own preference is for the curve of French, and he has used it in calculations for factors of safety for temperatures.

### Temperature Margins

Figure 2 reproduces the results of calculations for a 4-in. boiler tube of minimum Boiler Code thickness for internal pressures varying from 200 to 1400 lb. The inner surface of the tube is assumed to be 20 deg. higher in temperature than the saturation pressure of the steam. Assuming a transfer of 100,000 B.t.u. per sq. ft. per hr., the temperature of the outer surface has been calculated, also the stresses at both surfaces. Using the temperature limits given for these stresses by Lea and French, the maximum-temperature curves have been plotted, from which the temperature margins have been taken. These temperature margins, which may be called

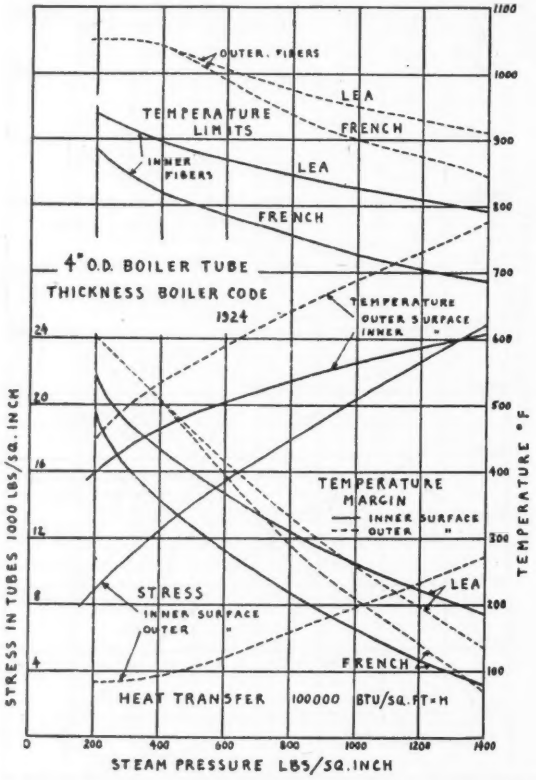



FIG. 2. RESULTS OF CALCULATIONS FOR A 4-IN. BOILER TUBE OF MINIMUM BOILER CODE THICKNESS FOR PRESSURES BETWEEN 200 AND 1400 LB. PER SQ. IN.

margins of safety, run from 480 to 600 deg. at 200 lb. down to 70 to 185 deg. at 1400 lb. All the curves referring to the inner surface are represented by full lines, while those for the outer surface are dotted.

### Stresses in Superheater Tubes

Convection superheaters show low heat-transmission rates, the maximum reported being about 6000 B.t.u. per hr. per sq. ft. for a straight convection superheater, which has only been increased to 8000 to 9000 for the usual interdeck variety. Steam velocities must not fall below 40 to 50 ft. per sec. or the temperatures of the outer and inner surfaces will equalize and tend toward the gas temperature.

Radiant-heat superheaters suffer much more severe punishment since the transfer rates may be as high as 60,000 to 70,000 B.t.u. per hr. per sq. ft., although the highest reported rate is around 30,000 B.t.u., and the tube is frequently exposed to the flame tips, both inner and outer, as well as to direct radiation. Temperature stresses play a very important part and the total stress is about twice that occurring in a convection-type superheater for the same pressure. The temperature margin has been reduced to 250 deg. F. at 200 lb., is only 200 deg. at 500 lb., and 100 deg. at 1200 lb. Under these conditions, the life of the superheater tubes must be much shorter, and bulges and failures must occur at short intervals with comparatively low pressures.

It is now plain from our discussion that:

1. A high-pressure boiler must consist largely of banks of tubes.
2. Headers of almost infinite variety are available up to at least 1400 lb. pressure.
3. Drums must be of small diameter even when forged, and should not contain in excess of 10 per cent of the water content of the boiler.
4. Many good designs are available if the usual canons of boiler designs are followed.
5. Up to at least 1000 lb. there will be no necessity of going to alloy steels, but above this pressure alloy steels are available and should be used if the temperature margins so require.
6. High-pressure work will show less difficulties of operation than lower pressures.
7. For higher superheats than 800 deg. alloy steels are indicated.

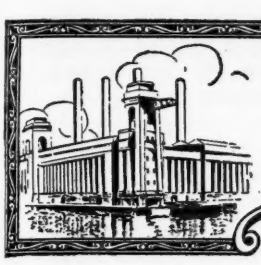
### Conclusions as to Best Type of High-Pressure Boiler Under Present Limitations

We may now state our conclusions as to the type of high-pressure boiler best suited to our present limitations.

1. Very high-pressure boilers (2000 lb. and over). Flash type, tubes 2 in. or less in diameter, no header, no drums, all welded joints, except at collectors and manifolds where flanged or coned joints should be used. These boilers may consist of a single coil for small outputs or multiple coils as in the Benson boiler.

2. High-pressure boilers (800-1600 lb.). Water-level type, consisting of a bank of tubes of larger diameter than those indicated for the flash type, with walls not to exceed one-tenth of the outside diameter in thickness. Tubes to be expanded in headers or small-diameter drums whose thickness when exposed to fire should not exceed one-tenth of the outer diameter. Waterline drum should not contain when half-full more than 10 per cent of the water content of the boiler. The boiler should be high rather than low, so that the water in the tubes may be under sufficient static head to insure steadiness of steam and restrictions in discharge opening to steam drums should be sufficient to obviate serious moisture in the steam. Dry pipes or separators should precede the superheater. Steaming economizers should not be used, but the feedwater should be heated by economizer or the regenerative system so that little water heating is left to be done by the boiler itself. Water-cooled furnace walls should be used in sufficient amount to make the furnace repairs a negligible quantity.

3. With temperatures in excess of 750 deg. F., we must be content with a shorter life of tubes and be prepared to replace coils or tubes from time to time. The only alternative is the use of much-higher-cost alloy steel.



# LETTERS DIRECT FROM THE PLANT

## Position of Piston at Any Crank Angle

REFERRING to the method of determining the position of a piston at 90 deg. crank, published on page 150 of the January 15 issue, I believe your readers would be interested to know of a simple method of determining the position of a piston at any given crank angle. This method, which was first proposed by Professor F. Brix of the Russian Naval Academy, is sufficiently accurate for all practical purposes.

Along the cylinder's axis, from the center of the shaft O toward the outer dead center of the crank, we lay off the quantity $OC = R^2 \div 2L$, and through the point C we draw the line $CA^1$ parallel to the crank at the given angle, until its intersection with the circle drawn by the crankpin. The projection $a^1$ of the point $A^1$ on the cylinder axis will give us the desired position of the piston.

This method is simple and its correctness is proved by the following:

As shown in Fig. 1, $L_1$, L and R represent the piston rod, the connecting rod and the crank, respectively. When the crank R is at the dead center $A_0$, the piston will be situated at the point $B_0$, at a distance $B_0O$ from the center of the shaft, and $B_0O$ will be $L_1 + L + R$. When the crank R is turned through the angle w from the dead point $A_0$ the piston will be in the position B and at a distance BO from the center of the shaft. From the diagram, Fig. 2, we see that $BO = BC + CA^1 + A^1O$ or $BO = L_1 + \sqrt{L^2 - R^2 \sin^2 w} + R \cos^2 w$.

The distance x, traveled by the piston from its dead center position to the position it occupies when the crank has been turned through the angle w, is found as follows:

$$x = B_0O - BO$$
$$= L\,[1 - \sqrt{1 - (R^2 \div L^2) \sin^2 w} + R\,1 - \cos w)]$$

Expanding the term $\sqrt{1 - (R^2 \div L^2) \sin^2 w}$ into a range according to Newton's binomial theorem and dropping the fourth and higher degrees of the term $(R \div L) \sin w$, since they represent very small quantities, we find $x = R\,(1 - \cos w) + (R^2 \div 2L) \sin^2 w$ as the true distance traveled by the piston.

In the above term, the quantity $R(1 - \cos w)$ is the distance traveled by the projection of the crankpin on the cylinder axis, i.e., the theoretical distance traveled by the piston, and the quantity $(R^2 \div 2L) \sin^2 w$ is the actual distance traveled by the piston beyond the previously determined amount owing to the crank's indirect influence.

Taking, for example, the stroke of the piston as 5 ft. and the ratio $L \div R$ as equal to 5, this complementary quantity will attain its maximum value at the angle $w = 90$, when, according to the formula, $R^2 \div 2L \sin^2 w = 5\,(1 \div 2.5) \sin 90$ deg. $= \frac{1}{2}$ ft. $= 6$ in., which, we see, is a very considerable quantity.

The projection of section $A.A^1$ onto the axis $A_0A_1$ represents, with a sufficient accuracy, the quantity expressed by the term

$$R\,(1 - \cos w) + (R^2 \div 2L) \sin^2 w$$

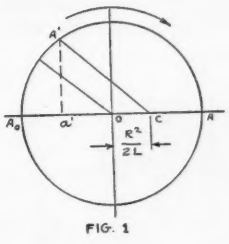


FIG. 1

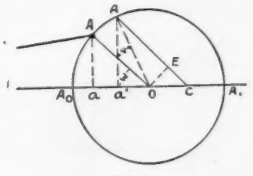


FIG. 3

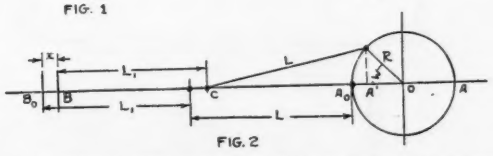


FIG. 2

FIG. 1. ILLUSTRATING METHOD OF QUICKLY DETERMINING THE POSITION OF A PISTON AT ANY GIVEN CRANK POSITION

FIGS. 2 AND 3. DIAGRAMS FOR PROVING METHOD USED ABOVE

We see from the illustration that

$$A_0a^1 = A_0O - Oa^1 = R - R \cos \text{angle } (A^1Oa^1)$$
$$= R\,[1 - \cos \text{angle } (A^1Oa^1)]$$

$$\text{Angle } A^1Oa^1 = w + v$$
$$\text{Cos } (w + v) = \cos w \cos v - \sin w \sin v$$
$$A_0a^1 = R\,(1 - \cos w \cos v + \sin w \sin v)$$

We then find from the triangle $A^1EO$ that

$$\sin v = OE \div OA^1 = (OC \sin w) \div OA^1$$
$$= (R^2 \div 2L)\,(\sin w \div R) = (R \div 2L) \sin w \text{ and}$$

$$\cos v = \sqrt{1 - (R^2 \div 4L^2) \sin^2 w}$$

Expanding the term for cos v into a range according to Newton's binomial theorem and using the second degree of the term $R \div 2L \sin w$ only, we find that

$$\cos v = 1 - (R^2 \div 8L^2) \sin^2 w$$

Substituting into the term for $A_0a^1$ the terms found as above for sin v and cos v, we have

$$A_0a^1 = R\,[1 - \cos w + (R^2 \div 8L^2) \sin^2 w \cos w + (R \div 2L) \sin^2 w] =$$
$$R\,(1 - \cos w) + (R^2 \div 2L) \sin^2 w + (R^3 \div 8L^2) \sin^2 w \cos w$$

The quantity represented by the term $(R^3 \div 8L^2)$ $\sin^2 w \cos w$ being very small, we can leave it out of consideration and the term for $A_0a^1$ then reduces to

$$A_0a^1 = R\ (1 - \cos w) + (R^2 \div 2L)\ \sin^2 w$$

On comparing equation 1 with equation 2 we find that

$$A_0a^1 = x$$

The term $(R^3 \div 8L^2)$ $\sin^2 w \cos w$, as already stated, is very small. It becomes of maximum value when $\cos w = 1 \div \sqrt{3}$ and when $R \div L = \frac{1}{4}R \div (8 \times 4^2 \times \sqrt{3})$ $(2 \div 3) = 0.003R$.

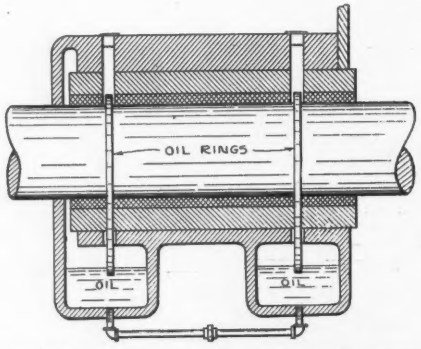
Assuming R as equal to 2 ft., the required distance would be 0.072 in.

When the angle w is = 0 deg., 90 deg., 180 deg., and 270 deg., the term $(R^3 \div 8L^2)$ $\sin^2 w \cos w$ is reduced to zero.

Helsingfors, Finland. N. GULJAEFF.

## Shaft Pumps Oil Out of Bearing

TROUBLE that for a time puzzled us developed from improper lubrication in a bearing on a 60-kw. generator. The bearing had two separate oil reservoirs with oil




SHOWING HOW BEARING TROUBLE WAS OVERCOME BY USE OF AN EQUALIZING PIPE

rings. Everything seemed all right for smooth, cool running but trouble was found in one end of the bearing.

When the ring in this end began to rattle, more oil was added. This relieved the situation for a time but later, on examination, I found that one reservoir was full while the other was empty. The shaft had acted as a pump. The method of correcting this trouble is shown in the sketch herewith.

Pleasant Hill, Mo. G. H. BROUGH.

## Reconnecting 220-v. Compound Motor for 110 v.

A SHORT TIME AGO, I changed a 220-v., six-pole, compound motor for operation on 110 v. by changing the commutator pitch. Without disturbing the armature winding, it was found that the armature had 79 slots and 158 commutator bars, the pitch of the coils being 1-54, forming a single-series progressive winding. The coils were one-turn strap copper, therefore the coils could not be reconnected with half the number of turns. Changing from wave to lap winding could not be done on a six-pole lap winding as a six-pole lap winding has six paths, whereas four are required. The last recourse was a double (four circuit) wave winding, which gave a series of three coils ending two bars behind the bars started on, the coils connecting to bars 1-53, -105, -157. This made a double-wave, retrogressive winding with four paths instead of two, which halved the voltage and doubled the current-carrying capacity of the armature, as was required.

To make this change, all of the top leads were raised out of the commutator necks while the bottom leads were not disturbed. The armature was then reconnected, with the lead pitch of 1-53. The shunt field coils were paralleled, giving three coils in series per path. New brushes, brush holders and series coils were ordered from the motor manufacturers. The brushes were ordered to be twice as thick as the 220-v. brushes, or wide enough to cover two bars and two-thirds.

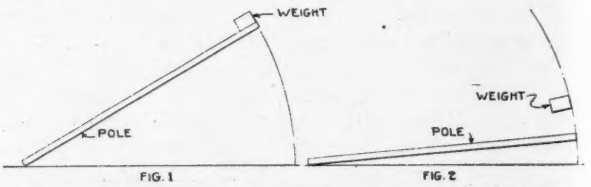
The armature leads had to be reversed to obtain the right direction of rotation and give cumulative compounding on account of changing the wave winding from progressive to retrogressive, which changes the polarity of the brushes in a generator and changes the direction of rotation of the armature in a motor.

The motor was repaired within four days and has operated satisfactorily ever since.

Woodward, Okla. HARRY J. ACHEE.

## Chimneys Break During Fall

C. O. SANDSTROM'S ARTICLE on this subject, published on page 528 of the May 1 number, interested me. I agree with him in general but am in doubt about the effect of centrifugal force. The fact that after a brick




WEIGHT RESTING ON FALLING POLE DROPS SLOWER THAN POLE

chimney has fallen it is always shorter while lying on the ground than it was while standing up proves that the velocity of the top of the chimney is comparatively small. Centrifugal force is equal to $WV^2 \div gR$ and it is only when V is large that centrifugal force amounts to much. My belief is that the breaks are due mostly to combined bending and compression.

Accompanying sketches show a method that I have used a number of times in explaining the breaking and bending action of falling chimneys. Hold a long, slender board in the position indicated in Fig. 1, with a weight lying on the free end, the other end resting on the ground. Release the free end and it will be found that before the free end strikes the ground there will be a considerable gap between the weight and the board. In other words, this proves that acceleration of the tip of the board is greater than the ordinary acceleration due to gravity. Mr. Sandstrom has illustrated it in another way. I believe that that portion of his explanation is correct.

Newark, N. J. W. F. SCHAPHORST.

## Cold Water Starts Balky Pump

DID YOU EVER have the steam boiler feed pump "lie down" just when water was badly needed in the boiler? If so, what did you do to keep the plant running and how did you do it? In such an emergency a man is quite likely to jump for the injector and keep it going until the steam pump properly behaves itself again. But how would you act when there was nothing but the battered old steam pump between you and a shut-down?

First, slow down the pump to 10 or 25 strokes per minute; make sure that there is a supply of water to draw from and that the water is not too hot to be handled. Sometimes, when the water end of the pump is too hot, a few buckets of cold water dashed over the water cylinder will start the pump to working again. If there is an overhead tank, a hose will be found to be just the thing for applying cooling water to a hot water end. Either open a bypass or an overflow so the pump will have no more than atmospheric pressure to work against. Open the little pet-cock on top of the water cylinder and note what, if anything, issues when the pump is working again. If air escapes, the pump is probably priming itself and may soon "pick up" water again. If nothing issues from the pet-cock, one or more water valves may be "stuck open" and a vigorous thumping of the water cylinder with a wood block or soft hammer may cause the valves to slip into action again. In case neither block nor soft hammer is available, place a bit of wood against the pump and hammer it with a one-pound hammer.

Sometimes dirt or trash puts a pump out of business by getting caught under a water suction valve and causing water to churn back and forth between cylinder and suction pipe. When this happens, only one end of the water cylinder is usually put out of business, the other cylinder-end working all right. A clue to the cause of trouble regarding the way water is behaving in the water cylinder may often be obtained by "listening-in" by means of your teeth, instead of your ears. Procure a short, small piece of hard wood, a folded 2-ft. rule is just the thing. Place this between the teeth, press the free end against the water cylinder or suction pipe and press the forefingers into your ears so as to cut off all external noise, then pay attention to the vibrations which pass through rule and teeth to your brain. If you have made a practice of using this rude stethoscope upon the pump when it is working normally, you will be able to learn much from the sounds in the pump when it is not working properly.

Many engineers have provided themselves with regular stethoscopes, the same as used by physicians. These instruments are not expensive and will tell a whole lot about what is going on inside of a pump or an engine. Usually, a boiler feed pump is so connected that at least two sources of water supply are available and one of these should always be the roof or storage tank belonging to the plant. Try the pump with each water supply in succession; then, when it has resumed working again, shift to the desired source of feedwater supply.

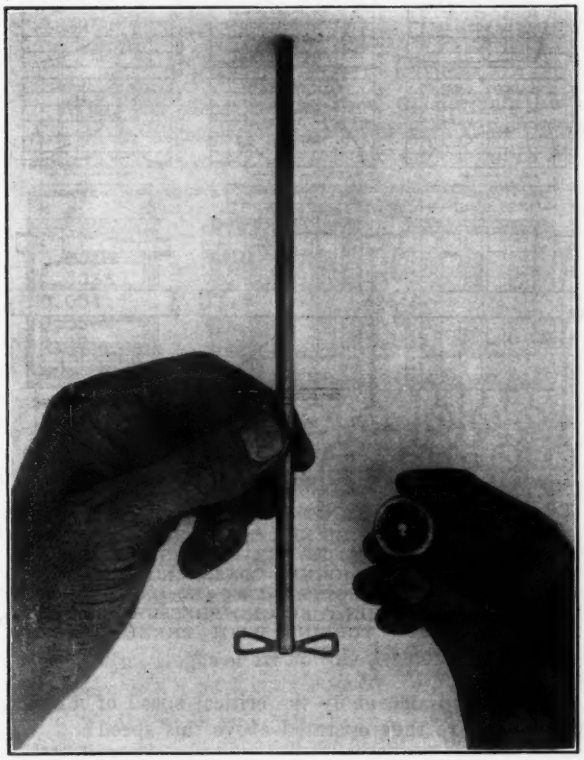
In case the feedwater is drawn from a stream or a pond, make sure by probing with a pole or a hook that the end of the suction pipe has not been closed by trash. In water obtained from a large spring, speckled trout, wedged tightly into the suction pipe, would put both the steam plant and the trout completely out of business.

Having gotten the pump suction to working, and delivering water through the bypass or overflow, try to shunt the water delivery into the boiler by opening and closing the valves, but be sure to open the valve to the feed pipe wide before closing off the bypass or overflow. Should the pump "balk" while thus shunting water into the feed pipe, apply the "boxwood-rule stethoscope" to the pump immediately over each set of delivery valves and the sounds heard will probably give a clue to the trouble.

Indianapolis, Ind. JAMES F. HOBART.

## Chain Link Makes Good Stem Handle

LIGHT KNURLED handle nuts of small steel or brass regulating spindles frequently snap off or get broken. When threaded on, the sizes are seemingly never of any available die size, because they are usually small and



FLATTENED CHAIN LINK IN SAWED SLOT REPLACES BROKEN-KNURLED STEM HANDLE

have many threads to the inch. A link of fairly heavy safety chain can be quickly applied to the spindle end, making an excellent handle, by sawing a slot in the spindle end the width of the blade and tapping in the center portion of the chain link; it should be pounded tight and a drop of solder used if it can be applied over the groove and bit of link center. This is a most practical little makeshift method of quickly repairing such spindle handles until new ones can be procured.

Missouri Valley, Iowa. FRANK W. BENTLEY, JR.

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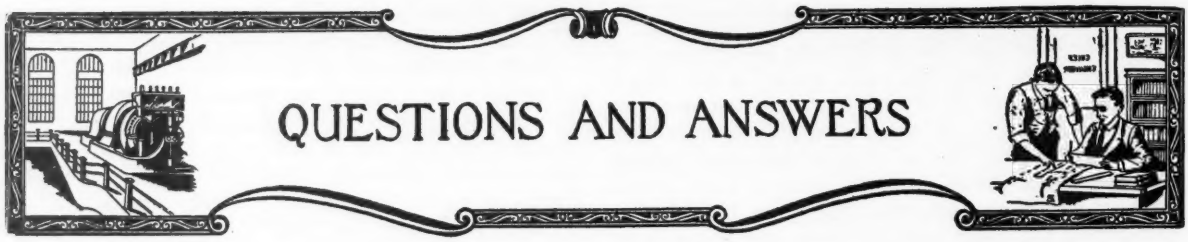
JUST WHEN the prize is within grasp, somebody usually kicks it away.




## Steam Turbine Practice

ANSWERS to the following questions will be greatly appreciated:

1. Define pressure staging, velocity staging and reaction staging in steam turbine operation.

2. In reaction staging, why does the fluid steam leave the blades at a greater velocity than at its approach?

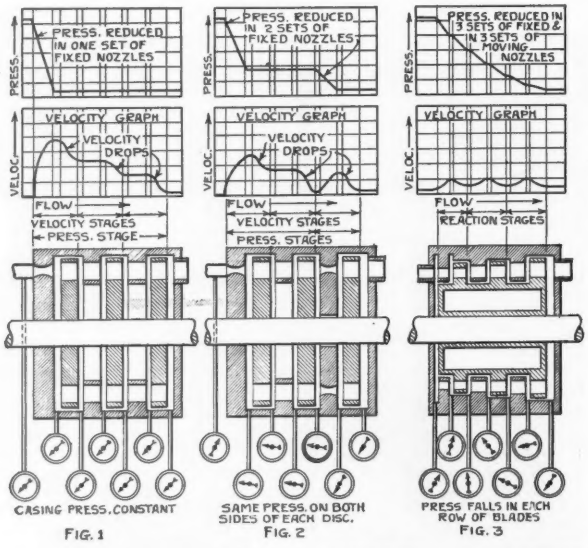



FIG. 1. IMPULSE TURBINE CONSISTING OF THREE VELOCITY STAGES IN ONE PRESSURE STAGE
FIG. 2. IMPULSE TURBINE CONSISTING OF THREE VELOCITY STAGES GROUPED TWO IN ONE PRESSURE STAGE AND ONE IN A SECOND PRESSURE STAGE
FIG. 3. REACTION TURBINE WITH THREE REACTION STAGES

3. What is meant by the critical speed of a steam turbine? Are they operated above this speed?

C. L. P.

A. A steam turbine stage may be defined as a section which comprises, or one of a number of well defined sections which comprise, the steam path through a turbine.

A velocity stage is that portion of the steam path in a turbine, wherein work is done by the impulsive force of the steam which consists of one row of stationary nozzles, or set of stationary guide vanes and the moving blades of the one runner which immediately follows the row of nozzles or vanes and on which the steam from the nozzles impinges. A velocity stage may begin with one row of either nozzles or guide vanes and always includes only one set of moving vanes.

A pressure stage is that portion of the steam path in a turbine wherein work is done by the impulsive force of the steam which comprises one or more velocity stages through which the steam passes consecutively, its first velocity stage having nozzles and the other velocity stages being all which follow up to the next set of nozzles. A pressure stage always begins with a set of nozzles but may contain, in addition, many rows of impulse stationary guide vanes and corresponding rows of moving blades.

A reaction stage is that portion of the steam path in a turbine wherein work is done by the reactive force of the steam which is composed of a set or row of stationary nozzles and that row of moving blades upon which these nozzles direct the steam. The steam, in passing through a reaction stage, suffers a reduction of pressure in both the stationary and moving blades. Reaction stages are frequently called pressure stages but it is believed to be better to reserve the latter name for the use indicated in the preceding paragraph.

2. In reaction staging, the steam expands in the blades, hence as it has larger volume after expansion than before, it must have higher velocity when it leaves the blades than it did on entering them.

3. The critical speed of a turbine is that speed at which its shaft vibrates most violently; at speeds well above or well below this critical speed the same turbine may run fairly free from vibration.

## Use of Accumulator Effect in Brine Cooling

IN OUR PLANT we have a brine tank for cooling milk. In this tank I have placed twenty-four 100-lb. ice pans which I keep filled with ice at all times so that when there is a big demand for cooling, the temperature of my brine will not rise so fast. At 32 deg. F., the temperature seems to be much more easily controlled than at lower or higher temperatures. With the ice pans filled, I can run this tank at 8 to 12 deg. below zero and when my peak load comes on the temperature does not rise suddenly.

1. Which is the better way to operate this tank; using ice pans as described above or using the brine alone, for cooling?

2. If the brine is at zero and the ice pans are used, at what temperature will the ice be and how many more B.t.u. will be in the ice at this temperature than when the brine is at 30 deg. above zero? J. C. F.

A. The accumulator effect you describe may better be accomplished if you had a reserve tank of brine in excess of the brine used in the regular cooling tank than if you employed ice, as the specific heat of ice is only about half of that of the liquid. The use of an accumulator effect for the purpose you mention is good;

the use of reserve brine would make its application more effective and less expensive.

2. Since there is no change in physical state, the ice would be 30 deg. lower in temperature at zero degrees than it is at 30 deg. above zero. If the ice has been in the brine for a reasonable length of time at any temperature between and including zero and 30 deg. above zero, the temperature of the ice will be the same as that of the brine.

At 32 deg. F. there is a change of physical state. In increasing the temperature from a point below 32 deg. to one above that temperature, the ice changes to water and it is necessary to account for the latent heat of fusion of ice which is 143.33 B.t.u. This amount of heat must be added to change the material from ice at 32 deg. to water at the same temperature. When water is frozen, this same quantity of heat must be rejected.

## Pump Air Chamber Leakage

WE ARE PUMPING fuel oil at 50 lb. pressure with a double-acting pump. We fill the air chamber with air and the gage stands still at 50 lb. for about 8 hr., then for 24 hr. it jumps from 10 lb. to 100 lb. Only about 2 in. of air is left in the chamber. How does it get out? The plug is tight. Would it be possible for the air in the air chamber to escape or be removed other than by bleeding it or by leakage? G. E.

A. There is at all times from 2 to 3 per cent of air in most water, probably as much if not more in oil, that is pumped and it might be possible that some of the air in the chamber is mixed and carried out in this manner; however, it is more likely that you have a leak in your air chamber.

It is hard to determine when air is leaking out as you cannot see it as you can in the case of water. Painting the surface and joints with soapy water may aid you in detecting a leak. If you place a snifter valve or cock in your suction line it can be slightly opened whenever necessary to replenish the air in the air chamber. Your condition may also be benefited by placing a larger air chamber on the pump. This air chamber could be made of standard gas pipe about 4 or 6 in. in diameter.

## Journal May Be Dressed by Hand

WHAT IS the best method of repairing the surface of a journal 9½ in. diameter by 18 in. long that has become scored $\frac{1}{32}$ in. deep in some places? This journal is on a cross compound engine running at 92 r.p.m. No lathe large enough to turn the shaft is available in town. Could it be dressed and polished with a stone? W. W. P. S.

A. A good mechanic can redress a journal satisfactorily by hand, but it requires great care. Four things are necessary: first, it is necessary that the journal is perfectly round at all points, then it should have the same diameter at all points, each elementary surface must be parallel to the axis of the shaft and the journal should be smooth.

In order to accomplish these requirements, it is best to proceed step by step. First select the point at which the scoring is deepest; then file this out, using a fine file for finishing. File a surface which may be more or less rounded, along the length of the journal, being careful that at all points this surface is parallel to the axis of the shaft. This can be done either by use of a micrometer depth gage or by calipering between a straightedge held down on the turned edge of the shaft and the surface is filed. Repeat the filing of elements all around the shaft, always following the initial method of checking for parallelism.

Having prepared a number of surface elements, file the intermediate surfaces by rocking your file so as to remove the high points. Constantly check for diameter, which, of course, should ultimately be the same at all points. Now examine your fillets and see that they are properly rounded.

Now you are ready for stoning. Be sure your stone has a flat surface, then apply it by rocking it over the surface to remove the file marks. Before completely removing these marks, check your work for diameter and parallelism at all points.

After the journal has been repaired, it is necessary to rebabbit the bearing. This can be done as described on page 413 of the April 1 issue.

## Flow of Air in Pipes

WILL YOU please let me know the formula for the flow of air through pipes of given sizes at given pressures? J. L. W.

| f | c | f | c |
|---|---|---|---|
| 0.003 | 83.0 | 0.0055 | 61.3 |
| 0.0035 | 76.9 | 0.006 | 58.7 |
| 0.004 | 71.9 | 0.0065 | 56.4 |
| 0.0045 | 67.8 | 0.007 | 54.7 |
| 0.005 | 64.3 | 0.0075 | 52.4 |

**The value of f varies with the diameter as follows:**

| d | f | c | d | f | c |
|---|---|---|---|---|---|
| 1 | 0.013 | 40.0 | 6 | 0.0045 | 67.9 |
| 2 | 0.0078 | 51.3 | 12 | 0.0036 | 75.3 |
| 3 | 0.0062 | 57.9 | 24 | 0.0032 | 80.1 |
| 4 | 0.0053 | 62.3 | 48 | 0.0030 | 82.8 |

RELATION BETWEEN DIAMETER OF PIPE, COEFFICIENT OF FLOW AND FRICTION

A. The weight of air flowing per minute for ordinary pressure is

$$Qw = W = c\sqrt{w\,(p_1 - p_2)\,d^5} \div \sqrt{L}$$

where: Q = quantity of air in cu. ft. per min.
w = density of the air corresponding to higher pressure $p_1$ in lb. per cu. ft.
$p_1$ = absolute pressure in lb. per sq. in. at high point.
$p_2$ = absolute pressure in lb. per sq. in. at low point.
d = diameter of pipe in inches.
L = length of pipe in feet.
c = coefficient of flow corresponding to the friction of the pipe and varying as shown in following table for different coefficients of friction f.

and the quantity of flow may be written

$$Q = \sqrt{(p_1 - p_2)\,d^5} \div \sqrt{wL\,(1 + 3.6 \div d)}$$

in which $K = 4.546\sqrt{1 \div 0.0028} = 85.9$.

# EDITORIAL COMMENT

## Our Changing Industrial Competition and the Engineer

Industry is passing through a transition period and the problems which must be met and solved are of a different nature from those encountered by past generations. There was a time when each manufacturer thought only of the competition of his neighbor engaged in the same business. Engineering developments have changed this and today the important competition is not between individual competitors but between industries.

Personal competition is still present but is largely lost sight of by the larger battle, wood against steel and concrete, silk and cotton against rayon, coal against gas and oil, ice against household refrigerators, the phonograph against radio and so on down the line, hardly any part of our modern civilization being free from this new competition.

Individual units of an industry have found it advisable to band together for the purpose of meeting this unfamiliar competition and devising ways and means of obtaining a share of the total business before they can begin an individual competition to determine how that portion shall be subdivided. Strong, nation-wide organizations, lumbermen, gas manufacturers, cement men, steel men, ice manufacturers and so on, have sprung up, spending millions in advertising to boost their own claims and discount those of competing industries. Naturally, consolidations and amalgamations of unheard of financial strength are growing up to meet these changing conditions.

By close study and application of power, the production end of industry has been highly developed; overdeveloped, in fact, when compared with standards and methods of distribution. This complex marketing situation brought about by various factors such as the development of the chain store, from producer-to-consumer movement, hand-to-mouth purchasing, installment buying and other schemes, will be simplified only by new standards and organization of business.

So far, the problem has been largely a national one but European competition is a rapidly growing factor which is demanding attention and will add a third element, making a three-cornered fight where each individual must fight for himself, his industry and his country.

Following American examples, European manufacturing and production methods have improved until there are many plants in Europe as well organized, equipped and managed as the best we have while their marketing and distribution channels, aided as they often are by industrial or international cartels, have effectively strangled American competition in some lines of production.

Just when foreign production methods will reach the point where it will become imperative for American manufacturers to make radical improvements in their methods of distribution is a problem which cannot as yet be foretold but that time is rapidly approaching. From an engineering background, Babson laid the laws of our modern business; Taylor and Gantt started our improved production methods; other engineers successfully solved standardization, simplification and research problems; and Hoover is attacking national and international problems of commerce.

Distribution methods, depending as they do fundamentally upon transportation and communication, come within the scope of the engineer and these problems, along with others such as seasonal operation, overexpansion and obsolescence, will eventually be solved from this angle; perhaps by engineers' work alone but more likely by engineers using engineering methods of approach and working in conjunction with the financial managers. The business cycle has been intelligently analyzed by this combination so successfully that many manufacturers have practically eliminated it from their experience and we have no reason to believe that they will not be equally successful in other attempts.

## Cahokia as a Pioneer

Courage is required to do pioneering, whether in opening up a new country or in developing new engineering methods. When a plant has undertaken such work, it is worthy of note and its designers should have credit.

In studying the equipment and progress of the Cahokia station, which was designed by McClellan and Junkersfield, certain features stand out as novel and requiring the courage of one's convictions to adopt them, especially in so-large a plant, whose continuous running is essential to the economy of the system.

Location in a former river bed on sand and silt, necessitated the raising of the ground level 12 ft. and use of levees for protection, which involved 1,200,000 cu. yd. of dredging in the river. Also foundation support was secured entirely by the use of concrete piles, 75 ft. long in the river wall and 20 ft. long on the side away from the river. Such conditions and methods had not appeared before in plant construction.

Use of pulverized coal exclusively and of water-cooled furnace walls had not been made outside the plants at Milwaukee and New York where they were developed and perfected. Their adoption at Cahokia, while not experimental, was a notable step in design of a new station.

In connection with the pulverized coal system of the second section, the first 15-t. Raymond mills and 20-t. Fuller Lehigh mills were put into commercial service; also 7½-t. high-speed Simplex mills on the unit system were first used on unit No. 5, two for each of three

boilers. Waste heat gravity type driers for the coal were adopted, also a pioneer installation.

On the electrical side, a 13,800-v. switchhouse was used, having the phases vertically isolated and with switchgear operating mechanism on a floor below the phase rooms. This was a new departure which has proved the wisdom of its originators.

That the pioneering was wisely done is shown by the fact that for several months during 1924, Cahokia showed the lowest B.t.u. per kilowatt-hour of any station then operating. Other central stations have since lowered the fuel economy record by using heat-saving equipment which is not justified at Cahokia because of low fuel cost. Here again, the designing engineers have shown good judgment in avoiding the temptation to seek fuel economy at the expense of total cost per kilowatt-hour.

It takes courage to be conservative when conditions require conservatism as well as to pioneer when untried methods appear to be the best to use.

## Weights, Measures and Common Sense

Weighing, measuring and counting of commodities were developed and are used for the convenience of humanity. Left to themselves, people will use the standards and methods which they find most convenient. The only common-sense function of government is to see that instruments used for weighing and measuring conform to a recognized standard so that trade and exchange shall be fair to seller and buyer.

In everyday life, transactions are carried out in the most convenient unit: inches and subdivisions for small measurements; feet where they best serve; yards for the next class; miles for long distances; light-years for the immense distances of astronomy. For the man at work, there is little occasion to convert from one unit to another except, perhaps, from feet to inches.

For laboratory work or in factory processes involving a great amount of calculation, metric units, with their decimal subdivisions and multiples are available and legal. The system has been taught for years to all school children so that they can use it, if they find it desirable.

On what basis of reason can Government step in and demand that everybody use *only* the metric system regardless of convenience and preference? Division of units into halves, quarters, eighths, thirds and the like is found convenient, and universally used. Resulting dimensions are easily visualized. Division into tenths and hundredths is not easily made or visualized and the resultant units, starting with the meter, are not of convenient size.

It would be as sane to legislate that all articles must be sold by tens instead of by the dozen or gross, as to make illegal the use of units which have been developed by convenience of use.

Outlawing of present standards is advocated largely by those concerned with laboratory work and calculations. Those engaged in manufacture and trade find no difficulty in using whichever standard their work requires. What is the common sense of introducing another prohibiting law which would require another army of enforcement to prevent bootlegging in feet and pounds?

At present, 85 per cent of the world's manufactures are produced on the inches measurement basis and 50 per cent of its export trade is in English units. Only 37 per cent of export trade is in metric units. Why put the majority of manufacturing and trading in the outlaw class?

Recently, proposal has been made to change the inch to 2½ centimeters and the foot to 30 centimeters. Why, if the metric advocates want exact convertibility, not change the meter so that 2½ centimeters will equal 1 in.? Why make the change in the most widely used unit? The meter is not, as it was intended to be, a natural unit. It, as well as the yard, is a standard bar of metal—nothing else. Even that change would not make miles and kilometers, liters and quarts, or kilograms and pounds commensurate. And people would go on using half and quarter inches and pounds, counting by the dozen and quoting bonds and stocks by eighths and quarters to the end of time.

Representatives of the people would seem to do well if they took thought to represent the common sense of the people in this matter.

## Open Season on Slag

Slag and clinkers never find a welcome in the power plant and the operator is always on guard against them. Sometimes they can be eliminated by improving firing methods, changing designs or using different coals; at other times, the root of the trouble cannot be reached and some method must be found for dealing with the clinkers after they are formed.

Slagging of the lower rows of tubes is prevalent when boilers are operated at high ratings, and this has been dealt with more or less efficiently by various types of slag screens so placed as to protect the boiler tubes proper. Where such screens cannot be provided, or when slag builds up on them, some method of cleaning must be used.

Some companies take the boiler out of service and clean the tubes with shovels or picks, some use steam lances while the boiler is in service, and still others report that a cold stream of water is the most effective cleaning agent. One of the most novel and, it is reported, effective methods is the use of a shot gun loaded with bird shot.

A special shell with a small powder and large shot charge is used while the boiler is in operation. It is reported to be effective in breaking off the clinker without interrupting boiler operation or taking the boiler out of service. It is not known whether or not the operator is required to have a hunting license.

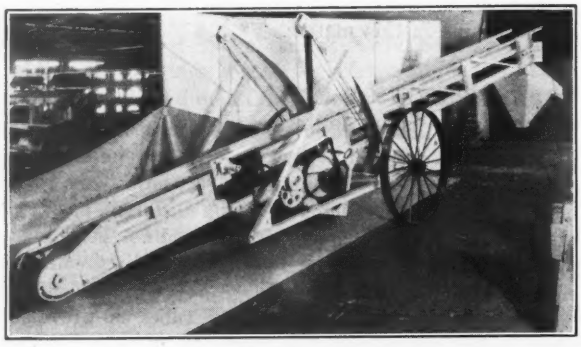
This is, of course, analogous to the machine gun method used for cleaning kilns in cement plants. The long rotary kiln makes an excellent target and the slag formed on the sides is shot off without damage to the lining and without an excessive loss of time.

Perhaps, in the years to come, the explosive engineer will assume an important position in the power plant field. During odd periods of the day, he might be stationed at the circulating water intake to shoot fish or ducks, which would be sold to the operators and thus reduce somewhat the direct expense of the explosive engineer.

# POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS

## Portable Flight Conveyor to Work with Car Unloader

DESIGNED to work with the Wagesaver car unloader, a new Wagesaver portable flight conveyor, known as the Type D, has recently been put on the market by Gifford-Wood Co., Hudson, N. Y. It has a handling capacity of 60 to 90 t. of coal an hour, depending on the grade and size handled. It is made in three lengths: 20 ft., 25 ft. and 30 ft. Flights are 15 in. wide and 4 in. high and are suspended between two strands of 2⅝-in. pitch chain of steel and malleable iron combination chain.



PORTABLE FLIGHT CONVEYOR DESIGNED TO WORK WITH CAR UNLOADER

This machine is equipped with a power raising and lowering device. Swivel wheels give added flexibility when maneuvering the machine into narrow spaces and also allow the machine to be used for stacking out coal in radial piles.

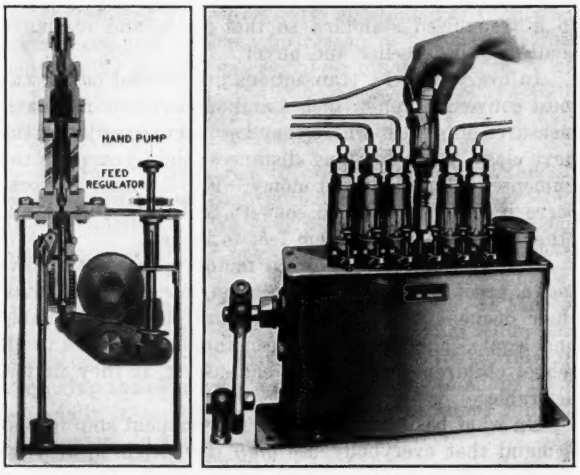
Drive mechanism and motor are placed to the rear of the center of the machine under the boom. This feature makes it possible to stack out coal to the full height of the conveyor without burying the wheels. The loading end is low and compact and is reinforced to withstand the shock of dropping doors and the falling of large lumps on the conveyor.

Two compression clutches are provided on the drive mechanism; one for throwing the conveyor in and out of service without starting and stopping the motor, the other for throwing in and out the raising and lowering mechanism. The boom can be raised while the conveyor is handling coal by merely throwing in the clutch which operates the raising mechanism. To lower the boom, the conveyor clutch is thrown out and the motor reversed before the clutch on the lowering mechanism is thrown in. A screening chute with dust deflector is provided with this machine if desired.

## Timing Lubricator for Diesel Engine Cylinders

TO MEET the demand for a lubricating device that would unfailingly deliver lubricating oil to Diesel engine cylinders in accurately measured quantities and at the exact instant desired, Manzel Bros. Co., Buffalo, N. Y., has placed on the market the Model 82 Manzel force feed lubricator for Diesel engines, shown in the attached illustration. This lubricator is built on the unit principle, a number of individual units being placed in a central tank or reservoir with one complete unit for each point to be lubricated.

Each unit consists of a single plunger pump which draws the oil from the reservoir and discharges it under pressure through a sight glass. This is intended to obviate the necessity for double pumps. The single plunger is operated, through a cam lever and an adjustable regulating rocker lever, by a cam on a hexagon driving shaft, this shaft being in turn driven by a ratchet, rotary or direct lever movement obtained from the shaft or some other part of the engine. The plunger itself opens and closes the intake port and measures the amount of oil pumped at each stroke, while a piston valve above the plunger opens and closes the outlet port.




LEFT—SECTIONAL VIEW OF PUMPING UNIT. RIGHT—INDIVIDUAL PUMPING UNITS ARE DESIGNED FOR EASY REMOVAL FROM RESERVOIR IF NECESSARY

During the forcing stroke, the plunger moves forward, closing the intake port. The oil entrapped between the end of the plunger and the piston valve is forced along the bore, while the light spring on top of the piston valve is compressed. When the piston valve

reaches the point where it uncovers the discharge port, it stops, while the plunger continues on, forcing the oil, until the stroke is completed, through the discharge port and into the glycerine-filled sight glass. The plunger is then returned to its starting position by a heavy coil spring, which forces it back against a stop attached to the cylinder.

During the return stroke, the piston valve follows the plunger until it is halted by the collar of the valve coming in contact with the cylinder casting. The plunger and valve then separate and a vacuum is created in the space between the two. The vacuum increases until the suction port is uncovered, when it is broken by the inrush of oil from the oil pocket on the side of the cylinder. Instantly more oil is drawn up through the tube, replacing that drawn from the pocket.

The pumping mechanism has a fluid seal to prevent air from being drawn into the pump. The amount of oil supplied depends upon the distance the plunger passes the intake port on its forward stroke. This is regulated by an adjusting screw and the pumping unit is designed for fine adjustment so that neither temperature nor viscosity of the oil will affect the regulation. The feed may be adjusted at any time, whether or not the lubricator is running. A separate hand pump is provided for each unit to enable the operator to flush any cylinder with oil at will.

The Model 82 lubricator is equally adaptable to the lubrication of air compressors. It is furnished in various combinations of feeds and with two compartments if desired for air compressor use. To secure timed lubrication in synchronism with the engine pistons, the lubricator cams can be set to harmonize with the action of the engine pistons. The lubricator is supplied in capacities ranging from 7 pt. in a single feed lubricator to 38 pt. with a 16-feed unit. Complete details of the mechanism and its operation, together with instructions for securing timed lubrication are contained in Catalog No. 82 issued by the manufacturer.

# Air Filters for Small Compressors

TO CLEAN air for small air compressors cartridge filters have recently been developed by the National Air Filter Co., Chicago, Ill., in capacities ranging from 150 c.f.m. to 800 c.f.m. The company has also announced a new semi-automatic filter for compressors ranging in capacity from 800 to 2500 c.f.m.

These cartridge filters, Fig. 1, resemble small drums, with the entire circumference of the drum covered with the filtering medium. Mats of multiple-ply copper ribbons, which have been immersed in oil, do the filtering. The filtering material is of solid copper to eliminate possibility of small pieces of the filtering medium tearing loose and getting into the compressor. An especially large storage space for dirt is provided by several layers of expanded metal, which are placed over the copper ribbon mats.

Cartridges can be unscrewed from their couplings on the compressor intake pipe, or wherever located, by means of a handle on the closed end of the drum. Placing the cartridges in a steam jet or in hot water cleans them thoroughly and immersion in discarded machine oil renews them quickly.

For capacities above 800 c.f.m. and up to 2500 c.f.m., the Simplex Jr. filter, Fig. 2, has been evolved. This is a larger drum filter, using the same filtering medium as the cartridge filter; it is semi-automatic, however, the drum being rotated through an oil bath by means of a hand crank. The axis of the drum is horizontal and one section of the filtering medium always rests in an oil reservoir placed at the bottom.

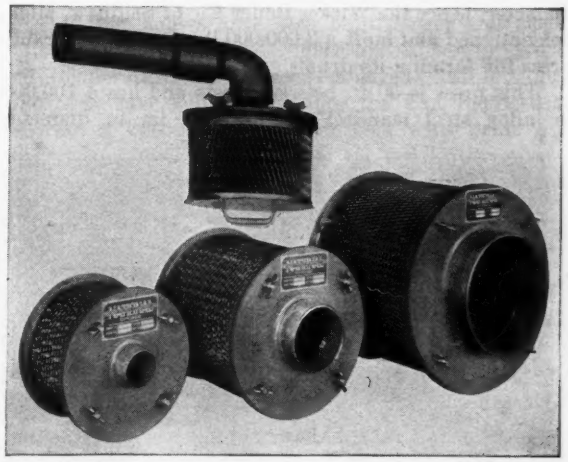


FIG. 1. SMALL CARTRIDGE FILTERS ARE SCREWED ON AIR COMPRESSOR INTAKE PIPE

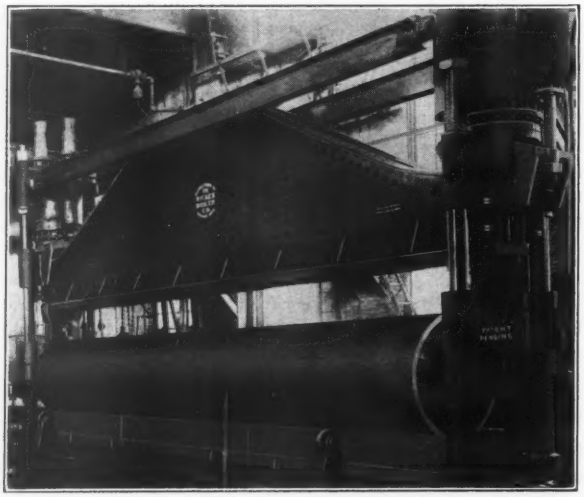
FIG. 2. FOR 800-2500-C.F.M. UNITS; DRUM IS TURNED BY HAND THROUGH OIL BATH

About once a week the drum is rotated one-fifth of its circumference by turning the hand crank. This action brings up one-fifth of the filtering area freshly cleaned and plunges the dirtiest one-fifth into the oil for cleaning. By a locking device on the handle, the drum can be locked firmly in any of the five positions. The sediment deposited in the oil falls into two sliding trays which are easily removed for cleaning.

# Hydraulic Press Forms Boiler Drum

INCREASED size and thickness of plate for drums in large, high-pressure, water-tube boilers has exceeded the capacity of bending rolls to form cylinders of small diameter, hence the Wickes Boiler Co. of Saginaw, Mich., has designed and built a 3,000,000-lb. pressure hydraulic press for forming its drums.

This press is 30 ft. between posts and has a 100,000-lb. alloy steel mandrel which is 36 in. in diameter.

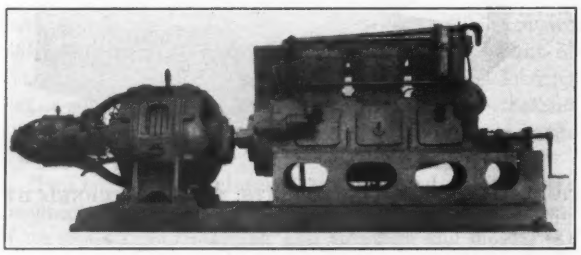


HEAVY BOILER DRUM FORMED BY HYDRAULIC PRESSURE MAKES POSSIBLE SINGLE SEAM CONSTRUCTION

Forming dies of steel casting rest on the lower platen of the press. The illustration shows a shell 48 in. in diameter, 1⅞ in. thick and 29 ft. long, which has been formed from a single steel plate.

# Climax Engine for Generator Drive

CLIMAX ENGINEERING CO., Clinton, Iowa, has adapted its large model R6U engine for use as a generator drive, mounting the engine on cast-iron side



ENGINE AND GENERATOR ARE FURNISHED MOUNTED ON CAST-IRON BASE

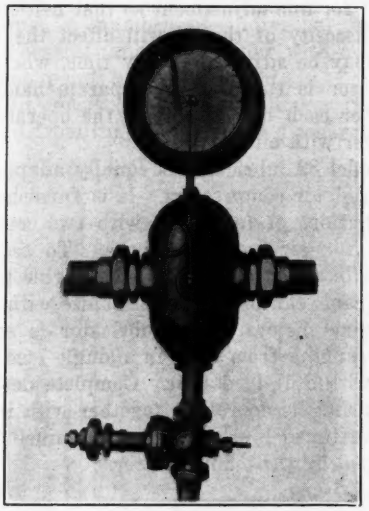
rails, which in turn can be set on a concrete or cast-iron sub-base, whereby the generator can be direct connected to the engine through a flexible coupling cushioned with rubber to eliminate undue shocks.

The engine can be supplied with or without radiator cooling and with a water-cooled exhaust manifold, which is particularly adapted for service where there is exceptionally heavy and long service or where room temperatures are high.

Another feature is the electric starter whereby this large engine can be started simply by the touch of the starter button. It is also equipped with dual ignition, both battery and magneto, insuring reliability at all times.

# New Steam Flow Controller

ANNOUNCEMENT is made by the Campbell Engineering Co., Short Hills, N. J., of a steam flow controller for automatically regulating steam flow. It is designed to control the rate of flow of steam in process work as, for example, to oil stills, where it is necessary to deliver steam to low pressure vessels at constant flow rates and it records and indicates such flow simultaneously. Recorder and indicator both give the



WATERMELON TYPE CONTROLLER WITH RECORDING GAGE

flow rate directly in pounds of steam per hour, which may be varied as the operator desires.

Essentially the controller consists of a combination of receiver, calibrated nozzles and recording or indicating instruments. There are two types, the "Pumpkinseed" type and the "Watermelon" type, as shown. The "Pumpkinseed" type has only one receiver and one orifice nozzle. This type is used where relatively small flows are desired. When larger quantities are to be used, the Watermelon serves and, when fitted with two calibrated orifices, is designed to proportion the flow to two points in the ratio of the orifice areas.

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SAN DIEGO CONSOLIDATED GAS & ELECTRIC CO., San Diego, Calif., has work under way on additions to its Station B, to include the installation of a new 28,000-kw. generating unit with auxiliaries. Completion is scheduled for October and the new unit will give the plant a total capacity of 63,000 kw. The work is being carried out under the direction of Byllesby Engineering & Management Corp., Chicago, Ill.

# Mechanical Engineers Meet at Pittsburgh

MANY PAPERS OF INTEREST TO POWER PLANT ENGINEERS PRESENTED AT SPRING MEETING OF A. S. M. E. ELMER SPERRY NOMINATED FOR PRESIDENT

PITTSBURGH, as host to the American Society of Mechanical Engineers during its Spring Meeting, May 14 to 17, opened the doors of its many industries to 800 visiting engineers and revealed the processes by which that city has been able to retain, through several generations, supremacy in the iron and steel industry. Although an excellent program of technical papers was given, the visiting engineers seemed to take an unusual interest in the inspection trips which had been planned by the local committee and probably half their time was taken up in being shown through steel and iron plants, piping and valve works, glass works, power plants, electrical factories and coal mines.

During the meeting, sessions were given over to fuels and heat flow, management, education and training for the industries, seamless tubing, railroads, hydraulics, machine shop practice, applied mechanics, central station power, materials handling and alloys. Many of these meetings were held simultaneously, which not only conserved time but also maintained continuous interest throughout the meeting.

At a business session held Monday afternoon, the presentation of the Lincoln Arc Welding Prizes took place. The first prize of $10,000 went to James W. Owens of the Newport News Shipbuilding and Dry Dock Co. for his paper and research work on arc welding. Professor Henri Dustin of the University of Brussels, Belgium, won the second prize of $5000 and Commander H. E. Russell of the U. S. Naval Academy won the third prize of $2500. Another award which was made at the dinner held on Wednesday evening was that of the Holley medal, given to Elmer A. Sperry of Brooklyn for research with gyroscopes which led to the development of a purely mechanical compass.

Announcement was made by the nominating committee of the following names to be voted upon before the annual meeting: For president, Elmer A. Sperry; for vice-presidents, Wm. Elmer, R. L. Daugherty and C. E. Gorton; for managers, Charles M. Allen, Robert T. Gates and Ely C. Hutchinson. Salt Lake City, Utah, was picked as the place for holding next year's Spring Meeting.

Many papers of interest to power plant engineers were presented at the meeting, among them being that entitled "Some Economic Factors in Power Station Design," presented by H. Boyd Brydon, Mechanical Engineer of the Byllesby Engineering and Management Corporation. This paper dealt with a discussion of capacity factors and average loads of steam turbines over a 16-yr. life period; it also contained an analysis of the costs of seven 60,000-kw. unit plants. One of these is to operate with steam at 400 lb. pressure, three with steam at 600 lb. and three with steam at 1200 lb., different reheating arrangements being provided in the 600-lb. and 1200-lb. plants. Preliminary layouts of the different plants were given and the author's analysis led to the conclusion that the adoption of the 400-lb. plant is preferable on the score of simplicity, ease of operation and cost.

With the growth of electric systems, larger and larger power houses have been built, larger and larger units have developed and higher and higher pressures and temperatures have been employed. All of these conditions have helped to reduce the heat required to generate a kilowatt-hour. Pointings with pride and gnashings of teeth have followed the publication of successive records of heat economies from one station after another. But to what extent have these things really been justified from an economic standpoint?

ELMER A. SPERRY

By setting high enough the capacity factor at which a proposed plant will operate, justification for increased expenditure to reduce heat consumption may easily be had. It is simply a question of getting the answer first. But is there not a tendency to overestimate this capacity factor? Is adequate consideration given, for instance, to the effect on the proposed plant of load increase as the years go on? Can we assert with any degree of confidence that we are reaching the saturation point in electric energy consumption? All of these questions were instrumental in bringing forth the discussion on the economic factors in power station design, resulting in the conclusions stated above.

### GAS AND PULVERIZED COAL MAKE ECONOMICAL FUEL

In a paper entitled "Combination Firing of Blast-Furnace Gas and Pulverized Coal," F. G. Cutler, Chief of Bureau of Steam Engineering of the Tennessee Coal, Iron & Railroad Co., told of his experiences along this line at the Ensley blast furnace plant consisting of six blast furnaces, where six Stirling boilers of 834 rated b.hp. are installed, each equipped with blast-furnace gas and pulverized coal burners.

In his discussion, he compared the conditions now existing to those prior to the installation of the new boiler equipment and showed that the operating costs of the blast-furnace boiler plant for fuel, as well as for labor and for repairs and maintenance, are materially lower than before. Based on the results secured, the author stated that at a new blast-furnace plant now being built by the Tennessee Co. at Fairfield, the same general method of regulation of gas, fuel and the storage system of powdered coal firing, with separate coal pulverizing plant, is being installed.

Ernest F. DuBrul, General Manager of the National Machine Tool Builders' Assn., criticized the methods now being used by many concerns in the manner of allowing for depreciation and, in his paper entitled "Some Common Delusions Concerning Depreciation," pointed out the effects of inflation of currency in creating illusions as to depreciation accounting. He showed the fallacy of usual accounting practice that takes into cost a depreciation allowance based on the original cost

of fixed assets. He also showed the necessity of calibrating the dollar measure of value consumed during each period, to allow for changes in the purchasing power of the dollar. The present common practice, he declared, results in overstatement of real profits by understatement of actual depreciation in some cases, and vice versa in others.

Then he showed graphically the difference between dollar accounts that are uncalibrated and those that are calibrated for purchasing power. The paper ended with the statement that "Profit is the end of business and it is the duty of management to earn true profit and not be deceived by bad figuring as to what that profit is."

### Training for Employes

That more training and education for all employes, including the semi-skilled and unskilled is needed, was the basis of a paper presented by A. C. Jewett, Director of the College of Industries, Carnegie Institute of Technology, on the subject "Industrial Cooperation in Education." The paper pointed out that this training can be effectively and inexpensively obtained through night schools which are conducted in nearly all the large cities of the country. The paper also contained data pertaining to night-school instruction in the Pittsburgh district.

An interesting point brought out was his opinion that every establishment should have someone whose duty it is to insure that every employe is properly and fully instructed in those matters which will make him more valuable. It should be his duty to see that existing educational institutions are used to the best advantage and to help to co-ordinate their teaching with the training of his establishment where this can be tactfully managed. In large establishments, at least one person should give this his entire attention.

"High-Pressure Steam Boilers" was the title of a paper presented by George A. Orrok, Consulting Engineer of the New York Edison Co., in which the author discussed the lines of further investigation which to him seem to offer the most promise. An abstract of this paper will be found on other pages of this issue.

H. G. Reist, Assistant Hydraulic Engineer of the Niagara Falls Power Co., described a plate-steel rotor for an electric generator. In designing this spider, the object was to obtain a construction having the least waste of material, ample strength, the fewest unknown quantities and one which could be economically produced by existing shop equipment. This spider is used in a generator driven by a vertical water wheel and weighs 220 t. The capacity of the generator is 40,000 kw., the spider supports 88 poles and runs at a speed of 81.8 r.p.m. Four of these spiders have been installed at the hydroelectric plant of the Philadelphia Electric Co., on the Susquehanna River at Conowingo, Md.

Recognizing the importance of having a continuous record of the height of water in remote points of an hydraulic system recorded at some central point, E. B. Strowger, Assistant Hydraulic Engineer of the Niagara Falls Power Co., presented a paper entitled "A Water-Level Gage of the Long-Distance Recording Type." This paper described such an instrument, consisting essentially of two Selsyn motors, one called the transmitter and one the follower, together with a float and a recording device. The transmitter is located at the point of measurement and the follower at some central point where the record is to appear. The position of the rotor of the transmitter is controlled by a float and the follower motor operates a pen carriage which records on a paper with suitable scaled divisions. The motors used are essentially induction motors with wound rotors excited from a common alternating current source. The rotor of the follower will follow the transmitter rotor due to the induced currents in the stators. The paper gave the important details for the proper functioning of the gage and presented drawings and photographs showing gages at present in operation.

# N.E.L.A. Plans Extensive Program for 51st Convention, June 4-8

FOR THE 10,000 delegates and visitors who are expected to attend the 51st Convention of the National Electric Light Association at Atlantic City from June 4 to 8, a well-rounded program has recently been announced by the committee in charge. In addition to the regular sessions of the Convention, many entertainment features have been arranged, with special provision for the women attending the meeting.

At 9:30 a. m. on Tuesday, June 5, the first general session will be welcomed to Atlantic City by Hon. Anthony M. Ruffu, mayor of the city. His address will be followed by reports of the treasurer, managing director and others. At 11:10 a. m., A. W. Thompson, president United Gas Improvement Co., will address the meeting on "Why the Investment Company?" and H. P. Davis, chairman of the board of the National Broadcasting Co., will speak on "Broadcasting—Present and Future."

On Tuesday afternoon, the Engineering Section session opens at 2:30 with an address by E. C. Stone, chairman of the section, followed by H. S. Bennion, director of engineering, with an address on "Purposes and Accomplishments of the Engineering Staff." Following this, A. D. Bailey, superintendent of generating stations, Commonwealth Edison Co., will speak on "Organizing the Industry's Engineering Research." W. E. Mitchell, vice-president, Georgia Power Co., will speak on "Spending Our Company's Money" and E. C. Stone, manager system development department, Duquesne Light Co., on "Engineering for the Future."

Simultaneous with the meeting of the Engineering Section will be a session of the Public Relations Section, at which committees will report and at which various phases of public relations problems will be discussed by prominent speakers. The Accounting Section and the Commercial Section will also discuss their particular problems on Tuesday afternoon.

### Public Policy Committee Session Will Be Broadcast

At the second general session, on Wednesday at 9:30 a. m., reports of committees and addresses on subjects of general interest to the public will be presented. On Wednesday evening, the Public Policy Committee meets at 8:30, its entire program being broadcast by the National Broadcasting Co. Melvin A. Traylor, president of the First National Bank of Chicago, will be the

principal speaker. Richard Crooks, tenor, will sing and music for dancing will be furnished by B. A. Rolfe's orchestra.

Third general session, on Wednesday, June 6, at 2:30 p. m., will discuss problems of railroad electrification, electricity and the farmer and will conclude with an address on "Power in Political Education" by Belle Sherwin, president, National League of Women Voters.

Three other general sessions will be held at which will be discussed relations between government and business, interconnection, functions of holding companies, electrical advertising and allied topics. The Convention will adjourn at 12:30 on Friday, June 8.

On the Million Dollar Pier, where most of the Convention meetings will be held, the exhibition space will be taken up by 206 manufacturers with a comprehensive display of electrical apparatus and merchandise.

Further information regarding hotel accommodations and details of the convention can be secured from N. E. L. A. Headquarters, 420 Lexington Ave., New York, N. Y.

## Hans J. Meyer Goes to Far East

ANNOUNCEMENT is made of the appointment of Hans. J. Meyer as an engineer of the Foreign Department of International Combustion Engineering Corporation. Mr. Meyer will sail on June 6 for the Far East.

Mr. Meyer's early training was with The Milwaukee Electric Railway & Light Co. His later identifications were as follows: District Engineer, Allis-Chalmers Mfg. Co.; Sales Engineer, Westinghouse Electric & Manufacturing Co.; Superintendent, Shreveport Gas, Electric Light & Power Co., Shreveport, La.; partner in the Consulting Engineering firm of Vaughn, Meyer & Sweet, Milwaukee; and partner with Charles L. Pillsbury and F. A. Vaughn in the consulting engineering firm of Charles L. Pillsbury Co., Minneapolis and St. Paul. During the war, Mr. Meyer was appointed Administrative Engineer, U. S. Fuel Administration, Bureau of Conservation, in which office he served with distinction.

Mr. Meyer became identified with Combustion Engineering Corporation in 1926 and was placed in charge of design and construction of complete fuel burning and steam generating equipment for the Kip's Bay Station of the New York Steam Corporation.

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DIVISION OF SIMPLIFIED PRACTICE, Department of Commerce, announces that as a sufficient number of written acceptances has been received for Simplified Practice Recommendation No. 56—Carbon Brushes and Brush Shunts, the project is now in effect as of November 1, 1927, subject to annual revision or reaffirmation by the industry.

# News Notes

ALLIS-CHALMERS MFG. Co., Milwaukee, Wis., announces that its Grand Rapids, Mich., branch office, in charge of G. C. Culver, has been moved to 310 Building and Loan Bldg., Grand Rapids.

WAGNER ELECTRIC CORP., 6400 Plymouth Ave., St. Louis, Mo., announces that E. D. Pike, after 26 yr. of service with the company, has been promoted to the position of manager of the San Francisco branch sales office.

INGERSOLL-RAND CO., 11 Broadway, New York, has added a seventh size to its line of portable air compressors. This new size (4¾-in. bore by 4-in. stroke) has a piston displacement of 82 c.f.m. It is intended primarily for use by contractors, public utilities, cities, towns requiring a unit of slightly larger capacity than the 4¼-in. by 4-in., 66-c.f.m. machine. The new compressor, like the other I-R portables, is equipped with a four-cylinder, tractor-type Waukesha motor. It is available on broad-faced steel wheels, on steel wheels with rubber tires, on I-R trailer mounting, on Ford or Chevrolet truck or without running gear for mounting on skids or railway cars.

EARL D. STEARNS, formerly of the Stearns Conveyor Corp. of Cleveland, Ohio, has become associated as vice-president with the Fairfield Engineering Co. of Marion, Ohio. He has had 20 yr. experience on conveying and structural work and has developed his anti-friction idler for belt conveyors as well as many other devices.

NATIONAL FLUE CLEANER CO., INC., Groveville, N. J., has recently appointed the following representatives: Walter G. Heacock Co., 30 Euclid Arcade, Cleveland, O., and 413 Penobscot Bldg., Detroit, Mich.; Jack Deerwester Co., 1621 University Ave., St. Paul, Minn.; Charles Zinram, P. O. Box 487, Erie, Pa.; Laib Co., Louisville, Ky.

ARTHUR L. MULLERGREN, Gates Bldg., Kansas City, Mo., engaged by the City Council, Benson, Minn., to make a survey for the proposed municipal power plant, has recommended the construction of such a plant to include a 600-kw. bleeder type turbine-generator unit with auxiliaries and suitable distribution system. The City Council will take action on this report at an early date. S. A. Berg is city clerk.

AMERICAN HOIST & DERRICK CO., St. Paul, Minn., announces that the partnership interest of W. O. Washburn was purchased on April 30 by Frank J. Johnson, the senior partner and one of the founders of the business. The business will be continued under the same name in the form of a corporation.

IT IS ANNOUNCED that Hedges-Walsh-Weidner Corp., with main offices at Chattanooga, Tenn., has just been formed by consolidation of The Casey-Hedges Co. and the Walsh & Weidner Boiler Co. M. M. Hedges has been elected president of the new corporation.

PAUL T. BRADY, aged 71, associated with the Westinghouse Electric and Manufacturing Co. for 34 yr., and actively engaged in the electrical industry since 1881, died of heart failure on May 3 at the home of his son, Arthur J. Brady, in Portland, Oregon.

Mr. Brady was born in Cooperstown, N. Y., in 1856, attended Exeter Academy, served for several years with the American Telephone & Telegraph Company and in 1890 joined the Thomson-Houston organization, which later became part of the General Electric Co. In 1894 he joined the Westinghouse Electric & Mfg. Co., becoming special representative in New York City in 1907 and continuing in this capacity until his death.

Wellman-Seaver-Morgan Co., Cleveland, Ohio, has recently appointed the following representatives: Acme Well Supply Co., 136 Liberty St., New York City; Basil S. Burgess, Coal Exchange Bldg., Huntington, W. Va.; Eastern Steam Specialty Co., 270 Lafayette St., New York City; Walter G. Heacock, Detroit, Mich.; Steam Equipment Mfg. Co., Pittsburgh, Pa.; R. George Ward, 809 Harrison Bldg., Philadelphia, Pa.

Griscom-Russell Co., New York, N. Y., announces that it has just purchased the major portion of the Russell & Co. plant adjacent to its own factory at Massillon, Ohio. The newly acquired buildings include machine shops, boiler shop, tool room and other departments and give the company greatly increased manufacturing facilities.

Erie City Iron Works, Erie, Pa., has established a direct sales office at 1105 Leader Bldg., Cleveland, Ohio, under Eugene Smith, as district manager.

Boiler Engineering Co., Newark, N. J., has appointed Arthur H. Kennedy, 316 Glencoe Bldg., Duluth, Minn., to represent it in Minnesota, Northern Michigan and North Dakota.

Cement Gun Co., Inc., Allentown, Pa., announces that A. C. O'Donnell and R. N. Gillespie now represent the company in the contracting and sales departments of its Chicago office, 549 W. Washington St.

Buffalo General Electric Co., Buffalo, N. Y., has work in progress on the extension to the Charles R. Huntley steam plant to include the installation of four new boiler units, furnishing steam to a new 100,000-hp. turbine-generator with auxiliary equipment. Pulverized coal is the fuel and complete equipment for handling it will be installed for the new unit. Harvey M. Cushing is chief engineer in charge.

Dampney Company of America, Hyde Park, Boston, Mass., has appointed Maintenance Engineering Corp., 2000 Harrington St., Houston, Texas, and Joy & Co., Inc., 314 Tramway Bldg., Denver, Colo., as its representatives.

Linde Air Products Co., has opened a district sales office at 48 West McLemore Ave. in Memphis, Tenn., with H. N. Smith in charge as district manager.

It is announced that the Ingersoll-Rand Drill Co., 314 N. Broadway, St. Louis, Mo., was succeeded by Ingersoll-Rand, Inc., on May 1, 1928.

Ideal Commutator Dresser Co., Sycamore, Ill., announces that it has appointed Superior Supply Co., Bluefield, W. Va., as its sales representative.

National Aluminate Corp., a Delaware corporation with general offices at 6216 W. 66th Place, Chicago, Ill., announces that it has purchased the stock, names, patents, trade marks and good will of the Chicago Chemical Co. and the Aluminate Sales Corp., both of Chicago. The new officers are Arthur Meeker, chairman of the board; H. A. Kern, president; P. W. Evans, vice president, and H. J. Young, secretary-treasurer. Dr. G. J. Fink will remain at the head of the research department.

Afco Products Co. announces the removal of its main office from New Haven, Conn., to 11 W. 42nd St., New York, N. Y.

Crisp County Power Commission, Cordele, Ga., J. J. Williams, chairman, is asking bids until July 10 for the construction of a power dam and hydro-electric plant to have a capacity of 7200 hp. on the Flint River near Warwick, Crisp County. Emmet S. Killibrew, Albany, Ga., is engineer and J. E. Sirrine & Co., Greenville, S. C., consulting engineer.

American Engineering Standards Committee announces that Wm. J. Serrill, Assistant General Manager of the United Gas Improvement Co., has been elected Chairman of the Committee, succeeding C. E. Skinner of the Westinghouse Electric & Manufacturing Co., who has been chairman of the committee for the past three years.

Engineering Societies Employment Service, formerly located in the Monadnock Block, 53 W. Jackson Blvd., announces the removal of its headquarters to 1216 Engineering Bldg., 250 Wacker Drive, Chicago. A. Krauser is manager.

Bayley Blower Co., Milwaukee, Wis., announces the promotion of Charles H. Jackson to the position of general sales engineer and of Ernest Szekely to that of chief engineer.

# Books and Catalogs

The American Society of Heating & Ventilating Engineers Guide—1928; Volume 6, published by American Society of Heating & Ventilating Engineers, 29 W. 39th St., New York; 680 pages; 6 by 9 in.; cloth; price $4.00.

For the engineer who has heating problems to solve, the Guide forms the most up-to-date and practical handbook of information on the subject that is published today. It is now in its sixth year of continuous growth and, as might be expected, developments in the heating and ventilating field have made necessary the inclusion in the latest volume of a considerable amount of new text matter. Besides this, of course, all the data have been revised and brought up to date.

Important contributions have been made to the chapter on Calculating Heat Losses from Building, by the inclusion of coefficients of transmission for various combinations of materials, these figures resulting largely from the research work of the Society.

Another notable section is that on Steam Heating Systems and Piping, based on research investigations of the society's research laboratory at Pittsburgh. New data are given for hot water heating systems, oil and gas heating, automatic heat control and insulation of pipes and surfaces and the ventilation section has been completely revised.

In the manufacturers' section, many new and inter-

esting products are described. One of the important and beneficial changes is the placing of the index to the technical data section at the front of the book.

Tables of data and charts are particularly good and in a form that can be used conveniently, while explanation of fundamental principles and discussion of types of equipment are well-written, clear and comprehensive.

This book will prove of the greatest value either in designing heating and ventilating equipment or in operating it. It is recommended unhesitatingly to all engineers.

AMPLE AND PURE water supply for the cities of Palm Beach and West Palm Beach, Fla., was a difficult problem, due to the location of the former on a sand spit between the ocean and the salt water inlet, Lake Worth. Solution of the difficulty by securing a supply of filtered surface water is described in an article by Malcolm Pirnie of Hazen & Whipple, printed and distributed by De Laval Steam Turbine Co., Trenton, N. J.

W. H. NICHOLSON & Co., Wilkes Barre, Pa., has just issued bulletin 528, describing the Nicholson weight-operated trap to be used with steam, air and gas.

CHICAGO PNEUMATIC TOOL Co., 6 E. 44th St., New York City, in a 4-page illustrated folder, describes the new Pedwyn balancer designed to suspend, balance and lift portable tools and loads weighing from 10 to 150 lb.

"GASOLINE SERVICE STATION LIGHTING" is discussed in Nela booklet C-4, recently issued by Engineering Department, National Lamp Works of General Electric Co., Nela Park, Cleveland, Ohio.

WEAR AND Machinability of Cast Iron is the title of Bulletin No. 206 issued by the International Nickel Co., 67 Wall St., New York, discussing these properties and how they are affected by alloys of nickel and chromium.

BRISTOL Co., Waterbury, Conn., in bulletin No. 365, describes and illustrates various types of Bristol's counters.

BAYLEY BLOWER Co., 732-750 Greenbush St., Milwaukee, Wis., in a 4-page folder entitled "Cold Facts on a Hot Subject", discussed Chinook-Fin heaters.

FROM THE Esterline-Angus Co. of Indianapolis, Ind., comes a bulletin, No. 727, describing the installation of instruments and control equipment in the works of Fairbanks, Morse & Co. for recording the test data on electric motors.

"INDUSTRIAL PLANT Effects Marked Saving," an article on the operation of the Pittsburgh Plate Glass Co.'s power plant, is being sent out by Combustion Engineering Corporation, 200 Madison Avenue, New York City, who will be glad to furnish copies on request.

MANISTEE IRON WORKS Co., Manistee, Mich., in a 40-page, well-illustrated bulletin, describes Manistee pumps. In bulletin No. 7, the company describes and illustrates Manistee vacuum evaporators designed particularly for the salt industry.

HAGAN CORP., 304 Ross St., Pittsburgh, Pa., has just issued three attractive, well-illustrated bulletins covering various types of its equipment. Bulletin No. 101 describes Hagan master regulators; No. 102 describes Hagan balanced float controllers for low-pressure control; No. 103 discusses Hagan special control valves and governors.

ECONOMICS of Carbonization at Electric Central Stations is the title of an instructive paper by R. P. Soule, presented before the Metropolitan section of the A. S. M. E. It is a careful discussion of the economy of low-temperature carbonization as applied to central station practice, and the possible reduction in cost of electrical energy with its relation to conservation of coal supply. The paper has been reprinted and is being distributed by International Combustion Engineering Corporation, 200 Madison Ave., New York, N. Y., from whom copies may be obtained.

INGERSOLL-RAND Co., 11 Broadway, New York City, has issued a 140-page, two-color bulletin entitled "100 and 1 Ways to Save Money with Portable Compressors." This contains cost data on portable air compressors and air-operated tools; many of these data are presented on a man-hour basis for application to local conditions.

NORTHERN INDIANA PUBLIC SERVICE Co., subsidiary of the Midland Utilities, Gary, Ind., has plans under way for a new steam plant at Michigan City to have an initial capacity of 60,000 kw., with provision for future expansion. It is planned to begin work early in 1929. In the meantime, contract has been awarded to Westinghouse Electric & Mfg. Co. for a 60,000-kw. turbine-generator for this plant.

CELITE PRODUCTS Co., 1320 S. Hope St., Los Angeles, Calif., has just published bulletin No. 101 on Sil-O-Cel insulating materials and allied products.

WHITING CORP., Harvey, Ill., in a 4-page folder, No. 185, describes the Whiting hand power crane.

RELIANCE ELECTRIC & ENGINEERING Co., 1053 Ivanhoe Rd., Cleveland, Ohio, in bulletin 1087, discusses protection for electric motors.

BROWN INSTRUMENT Co., Philadelphia, Pa., in a recent folder, illustrates important features of the Brown electric flow meter.

S. OBERMAYER Co., 2563 W. 18th St., Chicago, Ill., has just issued a 16-page illustrated bulletin on Ramtite, a plastic monolithic furnace lining.

HAYS CORP., Michigan City, Ind., describes the Hays automatic $CO_2$ draft recorder Model B and other draft gages, in a recent 4-page bulletin.

MIDWEST STEEL STRINGERS for the modern factory are described in a 4-page bulletin by Midwest Steel & Supply Co., Inc., Bradford, Pa.

BRISTOL Co., Waterbury, Conn., in catalog 1800, describes and illustrates Bristol's recording liquid level gages.

"SPEEDING UP PRODUCTION WITH AUTOMATIC CONTROL" is the title of Bulletin No. 110, published by Monitor Controller Co., Baltimore, Md.

HALL METHODS of boiler water conditioning are described in a bulletin entitled "Out of the Darkness," recently issued by Hall Laboratories, Inc., 304 Ross St., Pittsburgh, Pa.

# Power Plant Construction News

**Ala., Talladega**—The Bemis Brothers Bag Co., 600 South Fourth Street, St. Louis, Mo., is said to be planning installation of power house at a proposed local mill on 1200-acre tract of land, lately acquired. Entire project will cost more than $2,000,000. J. E. Sirrine & Co., Greenville, S. C., are engineers.

**Ark., Saratoga**—The Oklahoma Portland Cement Co., Perrine Building, Oklahoma City, Okla., is reported planning a boiler plant and power house at a proposed local cement mill, for which a tract of more than 100 acres of land has recently been acquired. M. O. Mathews is general manager.

**Calif., Alhambra**—The Valley Ice Co. has taken out a permit for the construction of a one-story ice-manufacturing plant at 1013 Fremont Avenue, reported to cost more than $25,000.

**Calif., San Francisco**—The San Francisco Produce & Provision Terminals, Inc., Financial Center Building, plan the construction of a cold storage and refrigerating plant in connection with a proposed terminal unit at Laguna Street and Marina Boulevard. Entire project will cost about $3,000,000. Ellison & Russell, Pacific Building, are engineers.

**Calif., Santa Clara**—The Security Warehouse & Cold Storage Co., E. E. Chase, president, is planning the erection of a new cold storage and precooling plant, to cost in excess of $150,000.

**Colo., Belden**—The Empire Zinc Co. plans installation of power equipment in a proposed new milling plant at its Eagle Mine to cost about $200,000.

**Conn., New Haven**—The United Illuminating Co., New Haven, has plans maturing for a proposed steam-operated electric generating plant on Grand Avenue and will soon begin the superstructure. It is reported to cost in excess of $750,000, with machinery. Westcott & Mapes, New Haven, are engineers.

**Del., Wilmington**—The Pusey & Jones Corporation, manufacturer of machinery, will install power equipment in connection with extensions and improvements at its plant to cost about $350,000.

**Ga., Rome**—The American Chatillon Co., 393 Seventh Avenue, New York, recently organized, plans the construction of a power plant at its proposed rayon mill at Rome, Ga., where site has just been selected. Entire project is reported to cost more than $3,000,000. Lockwood, Greene & Co., 1 Pershing Square, New York, are architects and engineers.

**Ill., Chicago**—The Container Corporation of America, 111 West Washington Street, plans installation of power equipment in a proposed new paper board mill on Ogden Avenue, reported to cost more than $350,000, with machinery.

**Iowa, Cedar Rapids**—The City Council plans the installation of pumping machinery and auxiliary power equipment in connection with proposed extensions and improvements in municipal waterworks to cost in exces of $500,000. Alvord, Burdick & Howson, Hartford Building, Chicago, Ill., are consulting engineers.

**Kans., Kansas City**—George C. Newland, 29 South Eighteenth Street, is completing plans for a one-story ice-manufacturing plant, 90 x 125 ft., on State Street, reported to cost close to $40,000, with equipment. J. C. Braecklein, Kresge Building, Kansas City, is architect.

**La., Marksville**—The Central States Light & Power Co., Dubuque, Iowa, is reported planning the construction of a one-story ice-manufacturing plant at Marksville to cost close to $40,000, with equipment.

**Md., Baltimore**—The Bethlehem Shipbuilding Corporation, Key Highway, will install power equipment in second unit of new plant addition, for which plans have now been approved, reported to cost more than $500,000. Work on a first new unit is in progress. Company is a subsidiary of the Bethlehem Steel Co., Bethlehem, Pa.

**Mich., Iron River**—The Wisconsin-Michigan Power Co., Iron River, has approved plans for construction of new transmission line from Iron River to Phelps, reported to cost in excess of $20,000.

**Miss., Laurel**—The Eastman-Gardiner Co., Laurel, plans construction of boiler plant, pumping station and other mechanical buildings in connection with proposed rebuilding of local lumber mill recently destroyed by fire, with loss reported in excess of $400,000.

**Miss., Yazoo City**—The Planters Cotton Oil Co. has approved plans for the complete electrification of its plant and will proceed with work at early date.

**Mo., St. Louis**—The proposed new power substation to be constructed by the Union Electric Light & Power Co. at Clark and Fourteenth Streets will be one and two-story, 75 x 155 ft., estimated to cost $200,000, with equipment, instead of a smaller amount previously noted. LaBeaume & Klein, St. Louis, are architects.

**N. H., Keene**—The Boston & Maine Railroad Co., North Station, Boston, Mass., will install power equipment in connection with extensions and improvements in its local car shops. Entire project is reported to cost close to $100,000.

**N. J., Camden**—The Public Service Electric & Gas Co., Newark, N. J., has filed plans for a one-story power substation on Thirty-second Street, reported to cost more than $300,000, with equipment.

**N. J., Newark**—The Anti-Hydro Waterproofing Co., 285 Badger Avenue, will install power equipment in a new three-story factory addition to cost about $100,000. E. C. Epple, 9 Clinton Street, is architect and engineer.

**N. C., Charlotte**—The Hudson Silk Hosiery Co., Inc., South Boulevard, plans installation of power equipment in connection with a proposed addition to cost approximately $250,000.

**N. D., Grand Forks**—The Great Northern Railway Co., St. Paul, Minn., will install power equipment in a proposed locomotive repair shop and roundhouse at Grand Forks. Project will cost $130,000. T. D. McMahon, Great Northern Railway Building, St. Paul, is company architect.

**N. M., Silver City**—The Black Hawk Consolidated Mines Co. will install power equipment in a proposed new milling plant to cost approximately $100,000; it will be equipped for a capacity of about 125 tons per day.

**N. S., Halifax**—The Cowie & Drury Co., Ltd., Montreal, Que., care of F. W. Cowie, consulting engineer, has authorized immediate erection of a new ice-manufacturing and cold storage plant at Halifax, consisting of two seven-story units, with power house, estimated to cost $1,500,000, with equipment.

**N. Y., Albany**—The Ramsey Chain Co., 1031 Broadway, will install power equipment in a proposed new one-story plant on Troy Road. Entire project will cost in excess of $400,000.

**N. Y., Oswego**—The Oswego Candy Co., plans installation of power equipment in a proposed three-story addition at West First and Utica Streets, to cost close to $100,000, with machinery.

**Ohio, Canton**—The Timken Roller Bearing Co., Canton, has filed plans for a one-story power substation at its plant, 70 x 164 ft., to cost about $65,000, with equipment.

**Okla., Earlsboro**—A. J. Schlasser, Earlsboro, and associates plan construction of three-story ice-manufacturing plant near city limits, reported to cost more than $50,000, with equipment.

**Pa., Philadelphia**—The United States Gypsum Co., 300 West Adams Street, Chicago, Ill., will install power equipment in a proposed new mill at Philadelphia, for which plans are being prepared. Entire project is estimated to cost more than $250,000.

**S. C., Greenville**—The Saluda Crushed Stone Co., Capers Building, Greenville, plans installation of power equipment in connection with proposed rebuilding of plant at Hellams, near Greenville, recently destroyed by fire with loss reported at close to $200,000.

**Texas, Vernon**—The Common Council is completing plans for a one-story municipal light and power plant, 50 by 100 ft., reported to cost close to $35,000, with equipment. R. H. Stuckey, Vernon, is architect.

**Va.-Tenn., Bristol**—The Bristol Gas & Electric Co. will carry out an expansion and improvement program to cost about $500,000, including new power substations at Bristol and Elizabethton, and construction of 44,000 and 11,000-volt transmission lines.

**Wyo., Laramie**—The Western Public Service Co., Colorado Springs, Colo., has approved plans for construction of new light and power plant at Laramie, to cost about $80,000, with equipment.